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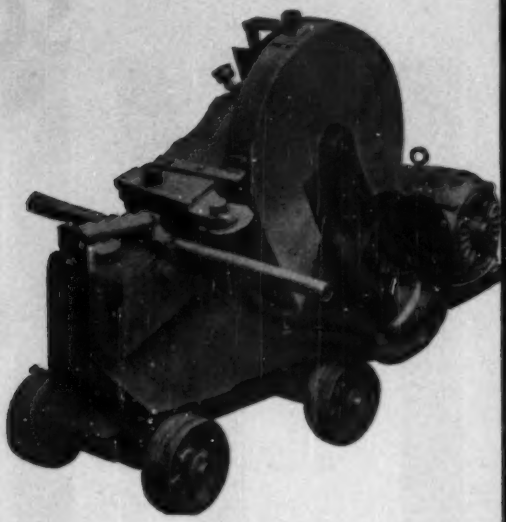

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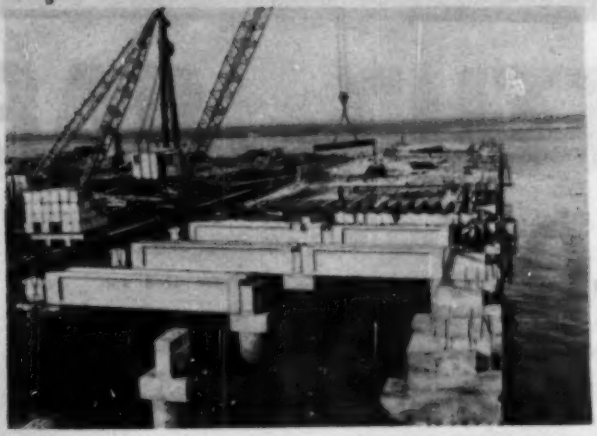

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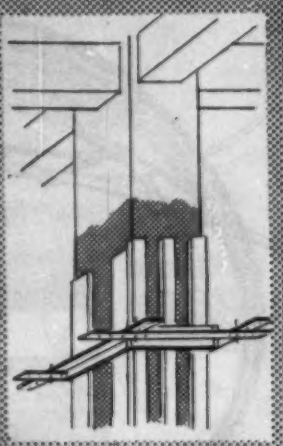

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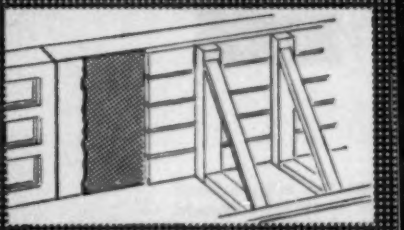

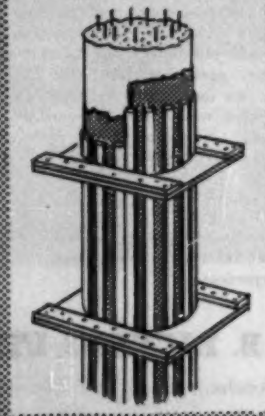

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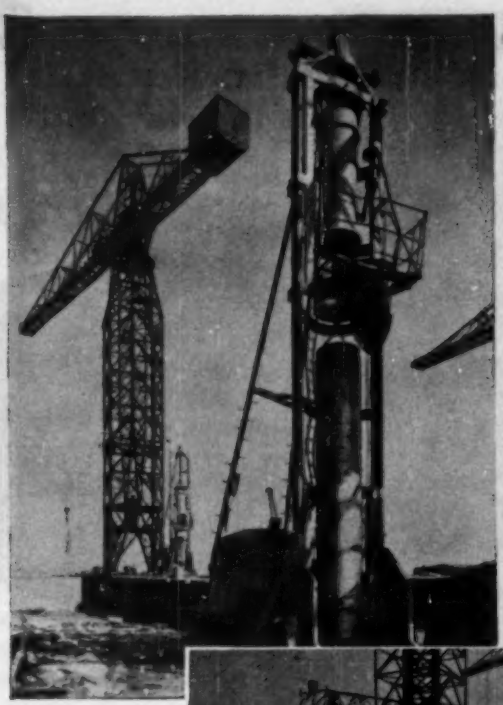

Waddington-Benoto Piles for new crane jetty

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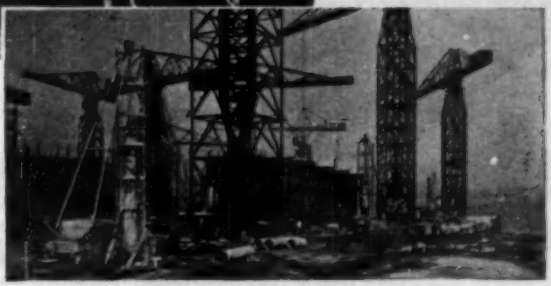

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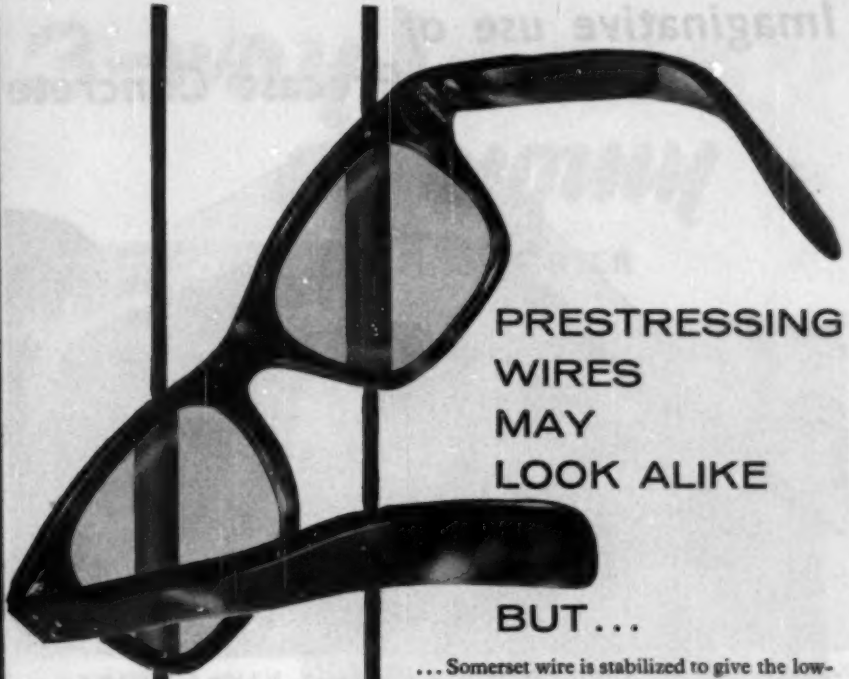

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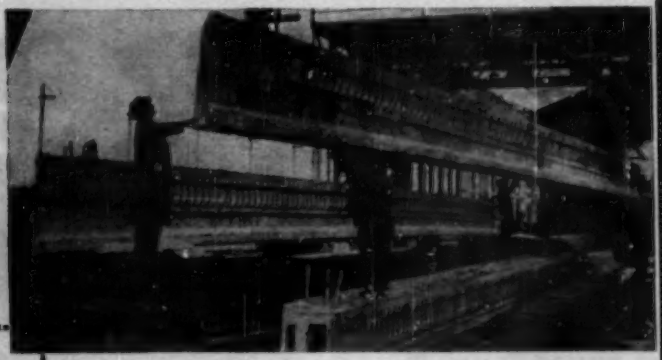

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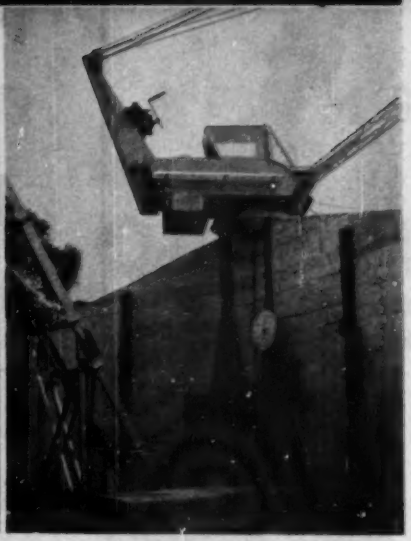

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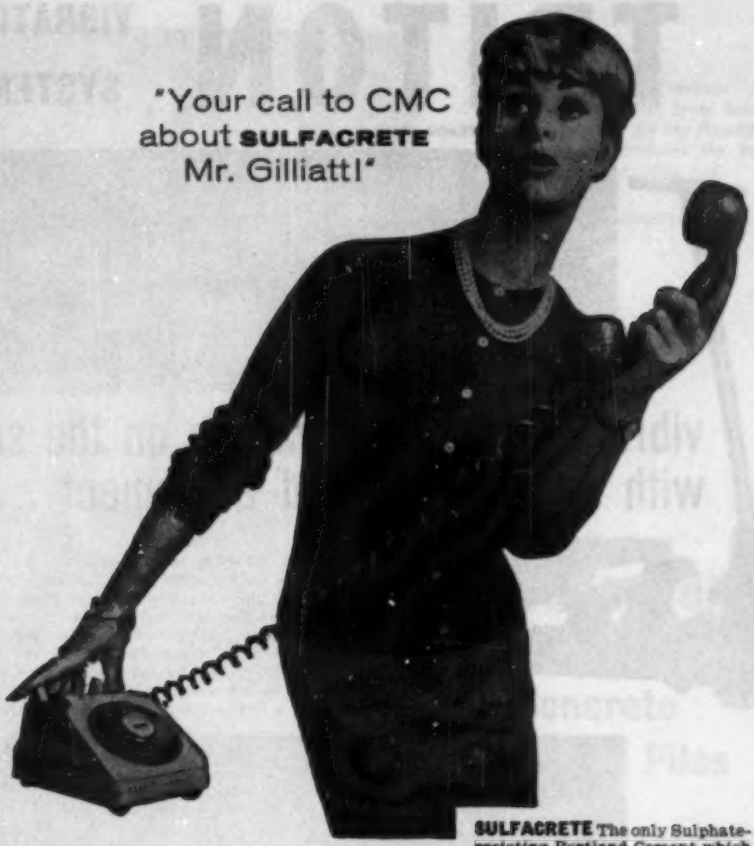

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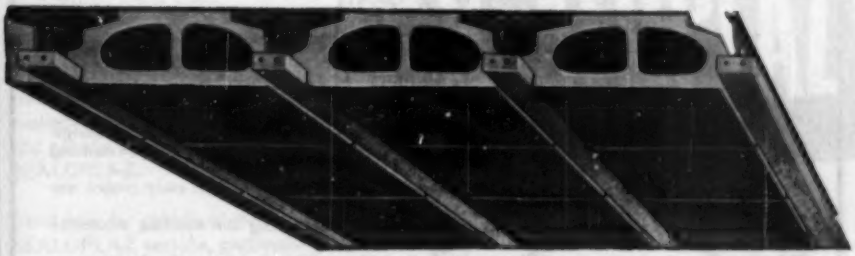

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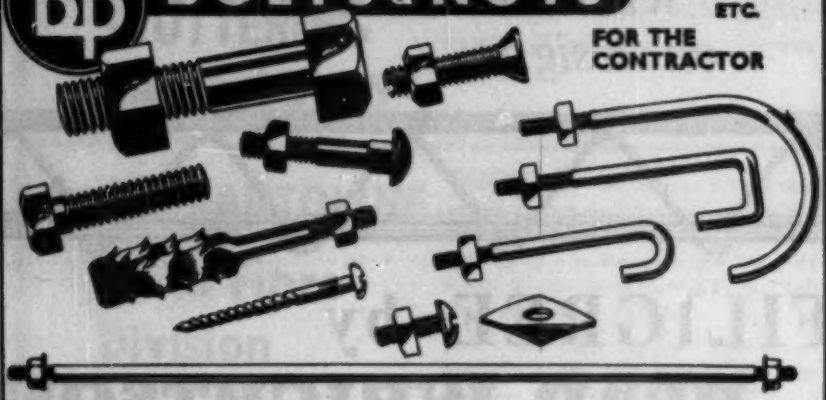

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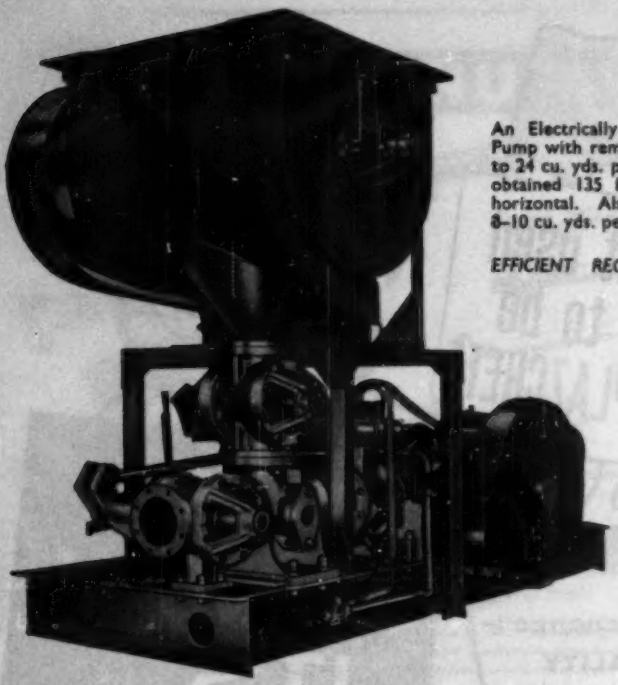

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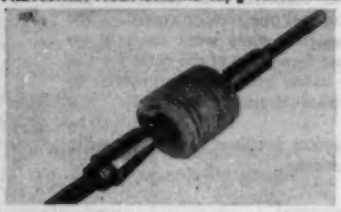

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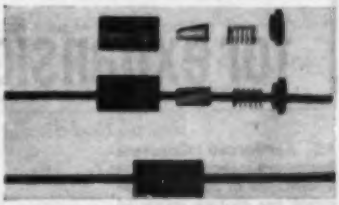

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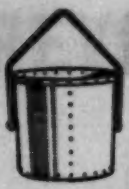

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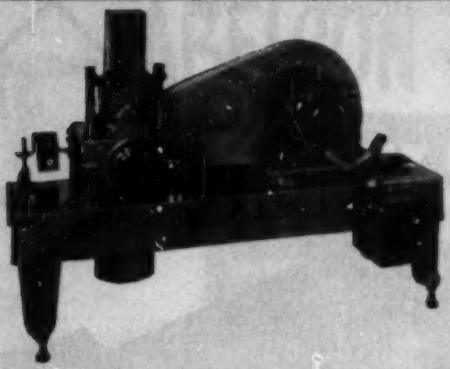

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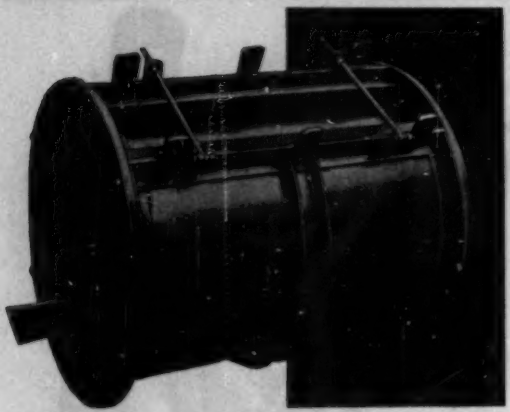

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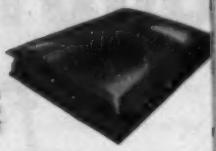

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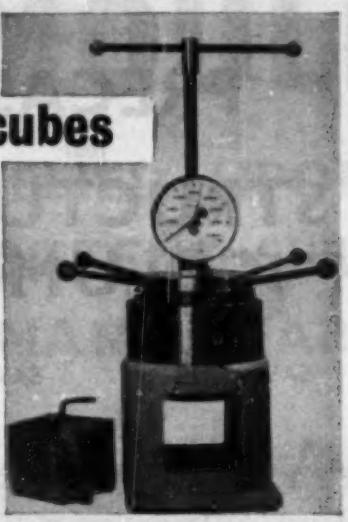

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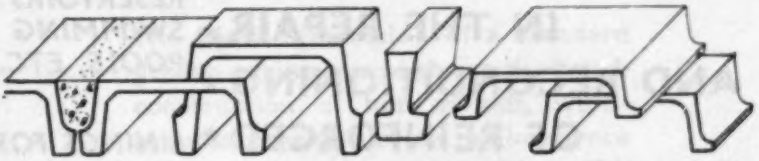

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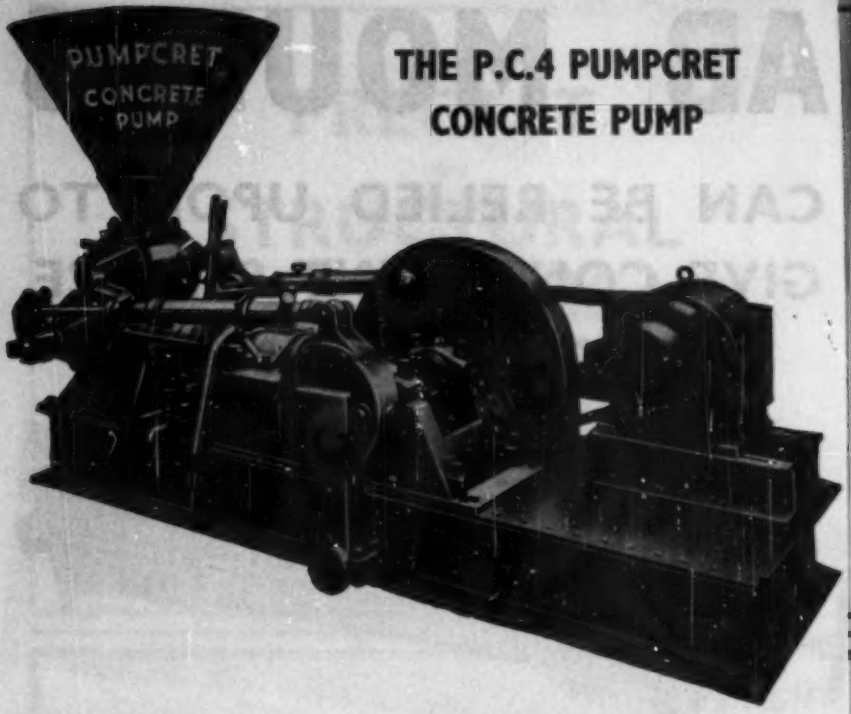

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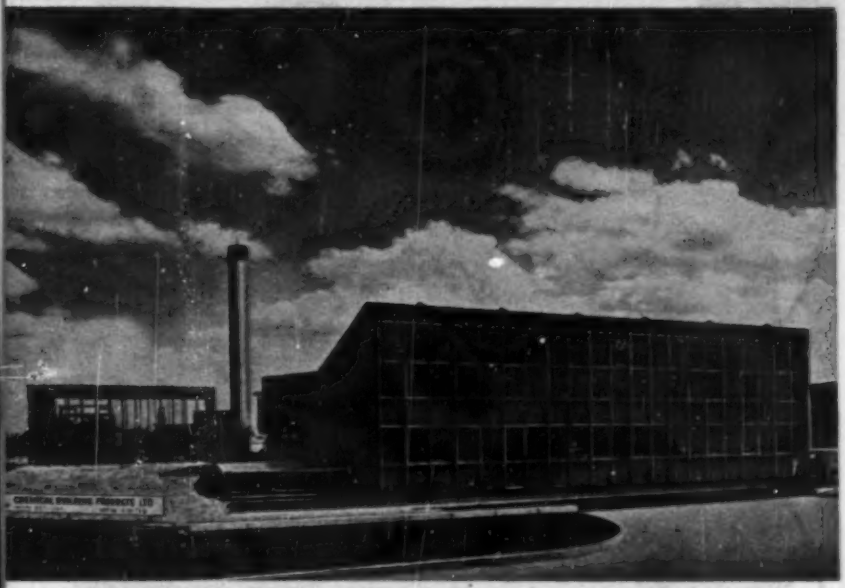

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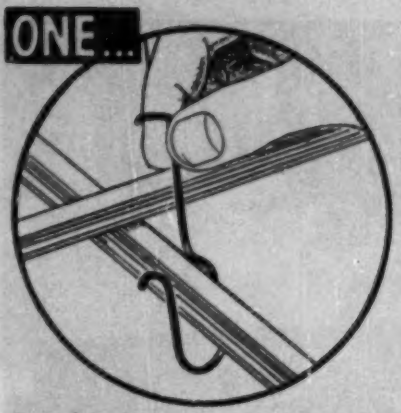

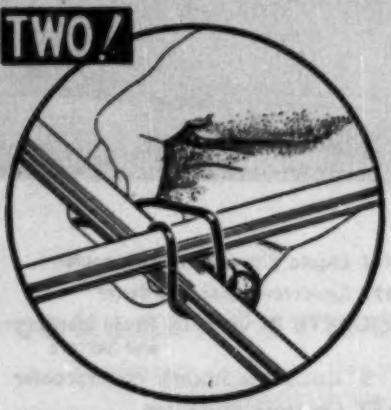

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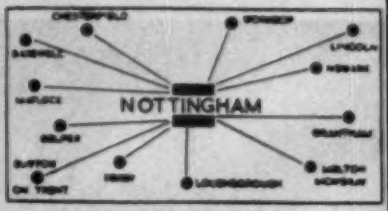

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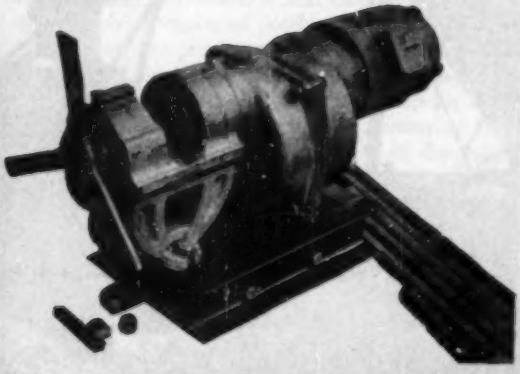

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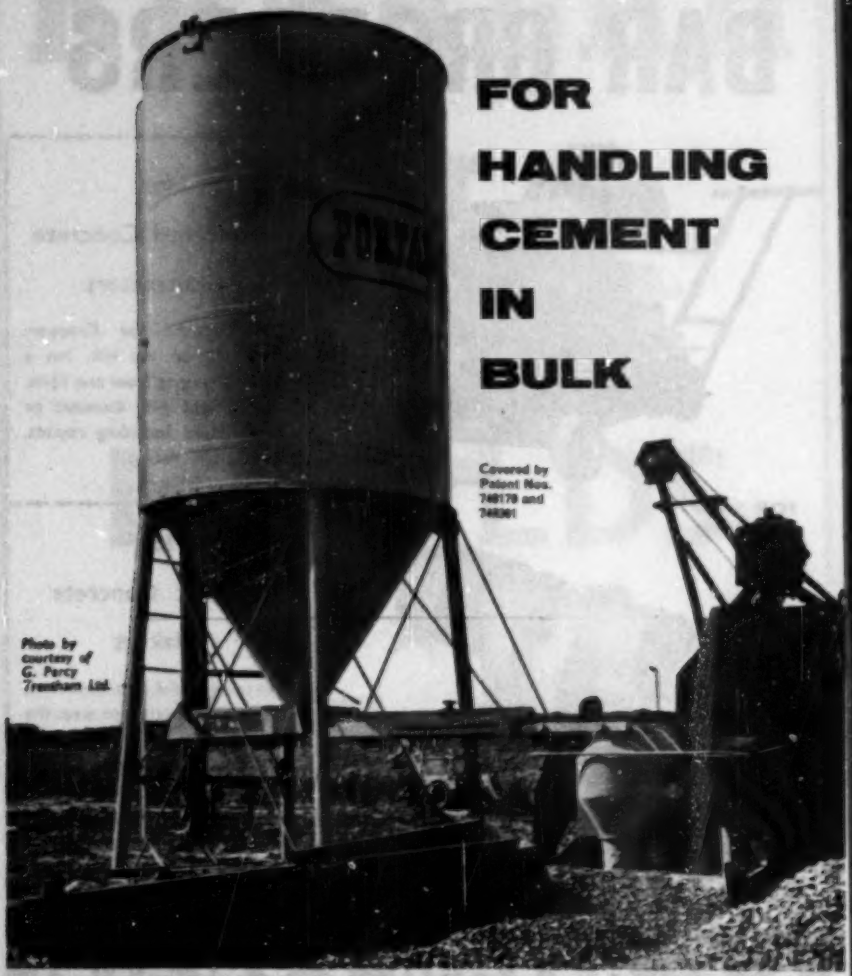

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Volume LVI, No. 12. LONDON, DECEMBER, 1961.

EDITORIAL NOTES

Agriculture and Building.

THE importance of Britain's largest industry, agriculture, is apparent mainly in times of national crisis. Whether the present economic state constitutes such a time or whether it is a transition period between a period of seeming prosperity and a less attractive aftermath is not for a technical journal to opine. What is fairly clear, however, is that British agriculture is facing a testing time which may be made the more severe if and when this country enters the European Common Market. It is just at such a time as this that farmers have to look to their affairs more keenly than in more prosperous times and under more protected conditions. An important feature of the industry is the structural equipment of farms and other properties. Buildings planned to give ease of working and to require little maintenance can result in noteworthy contributions to that increased efficiency which is said to be essential to enable British farm produce to compete with imported products. A renewed realisation, in many quarters, of the necessity to provide adequate buildings is indicated by the facts that a Farm Buildings Association was established a few years ago and that quite recently the Council of Industrial Design set up an advisory panel to deal with farm buildings. Concurrently with the action of the Council, but surprisingly unconnected therewith, are the efforts of the Royal Association of British Dairy Farmers, which organises the Royal Dairy Show. At the Show held in London in October last, a feature, introduced seriously for the first time in 1960, was an exhibition of farm buildings and other structures.

While present types of standard buildings are acknowledged by the Council of Industrial Design to have served reasonably well in the past, it is thought that the future requirements of agriculture might be better fulfilled by improved buildings which may be constructed of materials commonly used without adding to the cost of the structures. The advisory panel is to survey first the available standard components made of various materials, including concrete, the objectives being to recommend what may be suitable lines of development and to draw attention to aspects of current production which seem most promising. In this respect, it is certain that the investigations will show that many of the firms in the concrete industry catering for the farmer have anticipated the work of the panel in so far that their products are being continually improved or changed to meet changing requirements. Although in the event the structural exhibits,

utilising concrete, at this year's Royal Dairy Show may have been disappointingly few, the quality was encouraging. The complaint that standard concrete structures lack flexibility in planning and ability to be altered if required is no longer valid since more than one firm of precast concrete makers now produce structural components that can be assembled, and even taken down and re-assembled, to give almost any desired type of building. Such designs can only result from knowing intimately what a farmer wants. In one instance, flexibility of planning combined with simplicity of design and manufacture is obtained by adopting a low-pitch roof (about 11 deg.) whereby a high Dutch barn can be combined with a lean-to roof of less height over a covered yard. In another design, a basic building is provided which can be extended lengthways or sideways without alteration to the original structure, and upper floors, or lofts, of prestressed concrete slabs can be introduced, also without alteration. At a conference held in Copenhagen in September last, some attention was given to improved methods of construction of farm buildings; in particular, " tilt-up " construction, although not new (see page 442), is considered to offer some advantages.

Although precast concrete has been a feature of farm structures for very many years, prestressed concrete is by no means so generally used, one reason given being that the more slender members may not so well withstand the knocking about to which they are likely to be subjected in use or during erection by semi-skilled workmen. The particular requirements and the indeterminate loads and forces to which agricultural structures are subjected necessitates that design must be very much a matter of experience in this field. The saying that farm fences must be " pig tight, horse high and bull strong " is an expression of these special requirements. It is, however, axiomatic that, to produce economical buildings, the external loadings assumed should not only be adequate but should also not be excessive. In agricultural buildings examples of incidental loads, the effects of which should not be overlooked, are blows by passing vehicles on columns, gateposts and similar exposed members, and pressures due to piling materials against non-loadbearing walls. Although it is desirable that roof coverings are not blown off when the wind is slightly stronger than normal, over-estimation of the total wind force on a structure can result in extravagant construction. It is impracticable, even if it were desirable, for all parts of a structure to have precisely the same factor of safety. Although the main frame of a building should have a higher factor of safety against probable loads than, say, the cladding, it may be thought that the concrete frames of many farm buildings err on the side of excessive strength and to some extent, therefore, here is a margin for a reduction in cost. Evidence of this was forthcoming during the War, when " near misses " of flying-bombs failed to disrupt the concrete frames of several farm buildings although the structures were not designed to resist such extraordinarily violent forces. The requirements of some British Standards relating to farm buildings are less severe than the recommendations for other types of buildings.

Consideration of design should also include the aesthetical aspect. Farm buildings are often prominent in the rural landscape and in general are relatively free from planning control. Their appearance is therefore of some public concern the more particularly, as the Council of Industrial Design observes, since many buildings are subsidised from public funds through grants under the farm improvements scheme. One factor in connection with appearance is that the

glaring off-white of ordinary asbestos-cement sheeting and of concrete structural members may often be discordant with a verdant background. There should be little difficulty or extra cost in imparting a pleasing hue to these structures.

Building Priorities.

CONSIDERATION today of building work, whether for agricultural, commercial, educational, medical, or industrial purposes, introduces immediately the question of Governmental control during the present period of restrictions on activities in building and civil engineering. Spokesmen for the Federation of Civil Engineering Contractors have stated recently that, while it will be some time before the Government measures have an appreciable effect on the amount of work in the civil engineering industry, there is no doubt that they will result eventually in restriction of expansion of the industry. In fact, the " pause " in expansion could be of benefit to the industry if it were used to prepare plans for the time when full activity could be resumed. Many civil engineering works connected with water supply, sewerage, and other public services should proceed so that, when restrictions are eased, the construction of houses, factories, and the like would not be retarded because of an insufficiency of these services. Reduction of activity at short notice is not practicable where large civil engineering works are concerned. Therefore the building industry, as is customary, is called upon to bear the brunt of the reduction, since it is probable that in this section of the constructional industry, adjustments of programmes can be made most readily. The restriction of building work means that some process of selection (" priorities " is the term used by economists) must be operated.

It would seem that factories which are immediately productive should be near the top of the list of priorities if the products are for export. Few would dispute the priority, as announced recently in the Queen's Speech, to be given to the construction of hospitals, and anyone with a knowledge of the housing problem in the cities in this country, arising from a real shortage of accommodation for the multitude with little or no capital, would not hesitate to place houses and flats (to let) in a favoured position on the list. Office buildings which provide accommodation for the operation of Parkinson's law need not be high on the list, if on the list at all, in view of the fact that so many buildings of this type are proceeding or have been completed recently. The announcement made by the Chancellor of the Exchequer regarding the building of educational establishments points to a reduction in the rate of construction of new schools except for scientific or technical studies; but why the exception, if it is true that there will be a surfeit of " scientists " in a few years? May one speculate as to whether it is a fact that so much school building is required? Are the present premises (and staff for that matter) being used to capacity? What business could carry on successfully if its establishments (premises and staff) were in operation for little more than two-thirds of the number of available working days in the year? It is not to be inferred that pupils should be expected to attend school for a greater number of days in the year than at present, but by staggering days of attendance, the present premises and staff should be able to deal with a greater number of pupils and at the same time the present excessive size of classes might be reduced. No doubt the educationists will have a retort to such speculations, but it should not be impossible to reduce the need to build quite so many of the " aquariums " which today pass for schools.

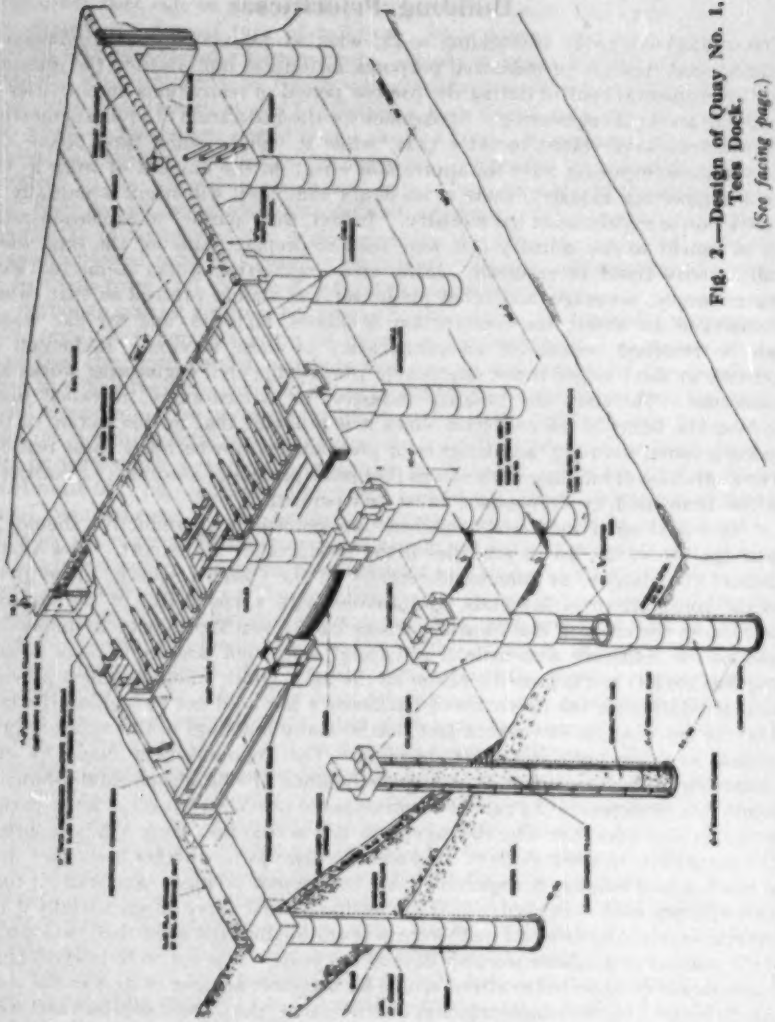

Fig. 2.—Design of Quay No. 1, Tees Dock. (See facing page.)

A Prestressed Concrete Quay at Tees Dock: The Substructure.

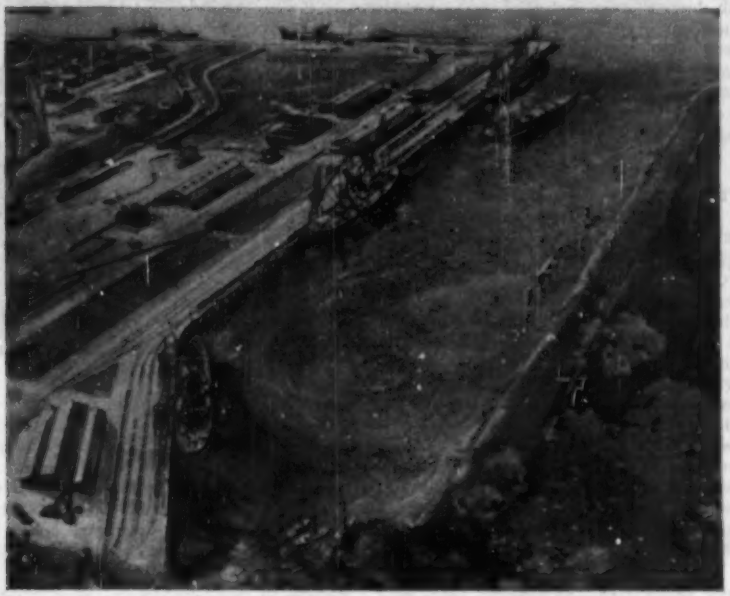

FIG. 1.—THE NEW QUAY AT TEES DOCK.

QUAY No. 1, now in the course of construction on the River Tees, is considered to be the largest prestressed concrete structure in Great Britain. The quay (*Fig.* 1) is 3220 ft. long and 90 ft. wide, and provides five new tidal berths having ultimately a depth of water of 37 ft. at low water spring tides. The general design (*Fig.* 2) is a deck comprising interlocking longitudinal beams spanning between transverse twin beams which are supported on concrete cylinders. The deck beams are covered with an 18-in. layer of lean concrete underlying a 6-in. layer of reinforced concrete embedded in which are the railway tracks and crane tracks. The two layers are cast insitu but the beams and cylinders are precast and prestressed.

A round-head is constructed at one end of the quay, and the massive fender blocks provided at intervals along the face of the quay are features of the structure. The site is reclaimed land and the quay is in a basin 3250 ft. long and 400 ft. wide on the south bank of, and at right-angles to, the river between Middlesbrough and Redcar.

Preliminary designs were commenced in 1954 and detailed designs in 1956 but, because of the Government's financial policy, construction of the quay was deferred until 1959. In the intervening period reclamation of the area between the site of the quay and the adjacent road proceeded by pumping sand, dredged from the river in the course of maintenance, into bunds. Dredging of the first portion of the basin also proceeded. This work provided useful information about the ground. When the tender documents were prepared it was realised that the original design was no longer necessarily the most economical. The original design included large precast reinforced concrete deck units weighing up to 80 tons each, but by then the development of prestressed concrete suggested that a more

economical scheme might be possible, and an alternative design with individual prestressed concrete elements weighing not more than 15 tons each was prepared. Both designs were included in the tender documents. In the tender accepted, the prestressed concrete scheme proved cheaper than the alternative in reinforced concrete and construction proceeded in accordance with the prestressed concrete design.

Site Investigations.

The preliminary investigation of the site required boring and sampling of the ground and pumping tests to establish the feasibility, or otherwise, of constructing the quay in the dry. It was found, however, that the slag embankments enclosing the site were extremely porous and would be costly to seal, and that ground suitable for the foundation of a gravity structure did not generally occur at a reasonable depth. From various preliminary designs which were prepared, it was determined that an open-type structure was the most economical, a conclusion which was confirmed by experience of the free-standing nature of faces dredged in the lower marl.

The bed-rock is solid Keuper marl overlain successively by about 50 ft. of disturbed marl, 10 ft. of boulder clay, and

Fig. 3.

between 5 ft. and 20 ft. of fine sand. The boulder clay and the disturbed marl do not differ greatly except for the inclusion of foreign particles in the former. The disturbed marl increases in hardness with depth but there are intermediate strata of soft soil until the solid marl is reached. Difficulty was experienced in sampling satisfactorily the disturbed marl, resulting in the validity of the foundation

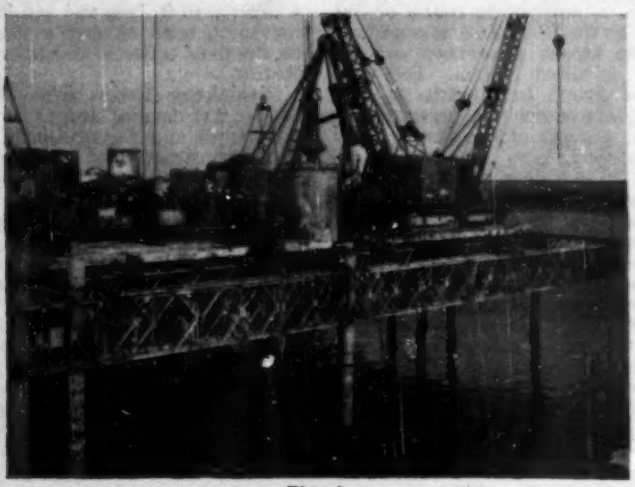

Fig. 4.

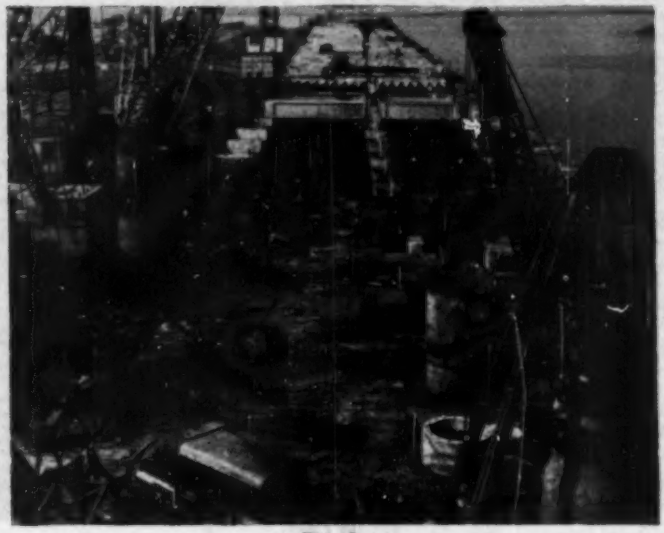

Fig. 5.

calculations being doubted. Consequently further investigations were made and included boring, sampling and testing of the soil, insitu plate-bearing tests, and applying a 1000-ton test-load to one of the cylinders forming the substructure.

In the plate-bearing tests, loads up to 100 tons were imposed on 12-in.-diameter tubes filled with concrete and these tests confirmed that the softer layers of the disturbed material would not support the working loads without excessive differential settlements. The conclusion formed at this stage of the investigation was that no satisfactory foundation relying on end-bearing alone could be provided above the level of the solid marl.

A cylinder was built on soft ground likely to settle excessively. The space between the cylinder and the excavation was grouted. Cables which could exert a force of 1000 tons were built into the cylinder, the lower ends being grouted into the rock and at the top were passed around steel yokes (*Fig.* 3). The load was applied by several hydraulic jacks placed between the yokes and a concrete cap cast on the cylinder. The results of this test were such that it was deemed practicable for the cylinders to be founded at the level originally intended, which was generally about 15 ft. above the solid marl.

Temporary Works.

After acceptance of the tender, a period of three months before the commencement of the work on site was occupied in planning the method of construction and the design of the temporary works, which are extensive.

There are 6346 precast concrete elements in the work and these are being made in a casting yard set up on the site. The cylinder rings are cast under cover in a shed but the beams and deck units are cast in the open. The concrete is mixed in a pan-mixer, the materials being supplied from a batching plant which incorporates two cement silos having screw-conveyor and automatic-feed discharge. The concrete is transported to the moulds for the deck units and beams on movable mono-rail bridges which cover the entire yard. A 15-ton derrick-crane is provided to place the cages of steel reinforcement in the moulds, and to stack the units when cast. Otherwise transportation of the precast elements about the yard and from the yard to site of the quay is on bogies running on rail-tracks. The deck

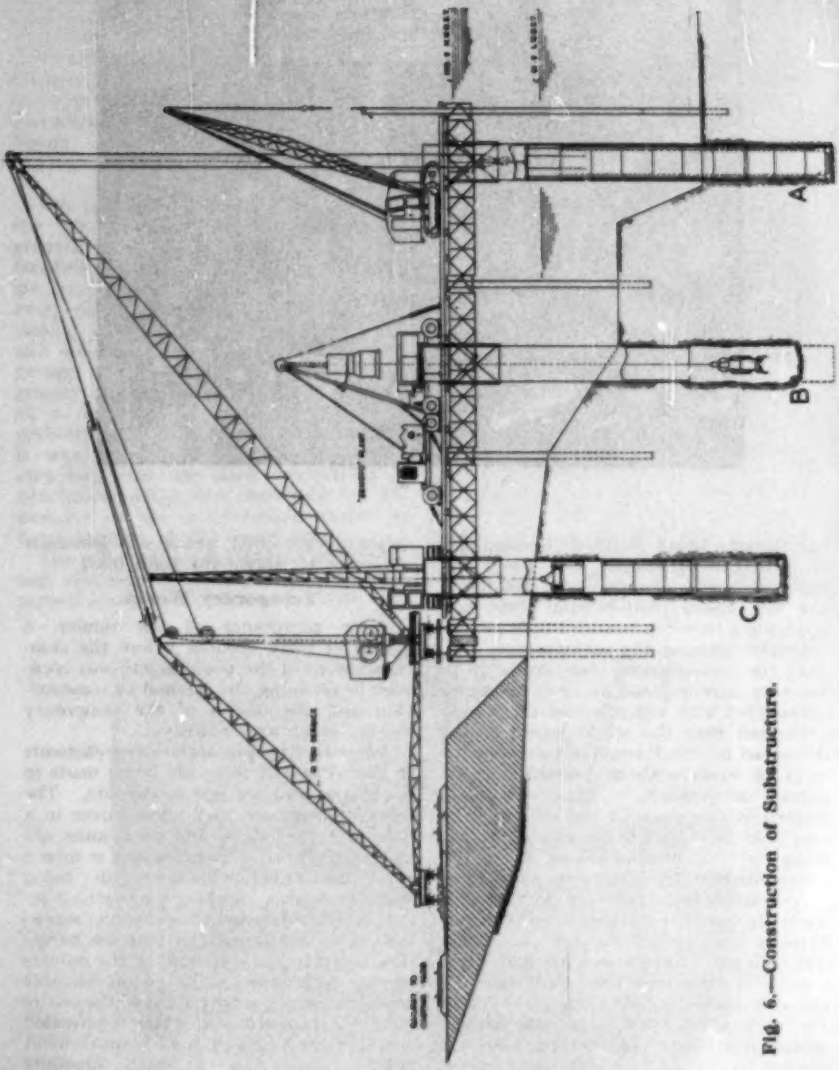

Fig. 6.—Construction of Substructure.

Fig. 7.

units, which mostly weigh between 10 and 15 tons each, are transported on articulated bogies on standard-gauge rail-tracks. The cylinder rings and reinforcement cages for the fender-blocks are transported on flat trucks. At the site, a temporary staging (*Fig.* 4), comprising cylindrical steel piles, Bailey-bridge units, and prefabricated interlocking panels of decking made of sleepers and steel beams, is provided to accommodate the heavy plant needed for the excavation for, and construction of, the cylinders. This staging, which is seen in the foreground of *Fig.* 5, advances as the work proceeds by dismantling at the trailing end and reassembling at the forward end. A 15-ton derrick-crane at the trailing end lifts the panels of decking and extracts the piles, and loads them into a motor-barge for movement to the forward end, where redriving the piles and re-assembly of decking is done by a crawler-crane (*Figs.* 6 and 7).

The Substructure.

The substructure comprises 330 concrete cylinders in transverse rows of three.

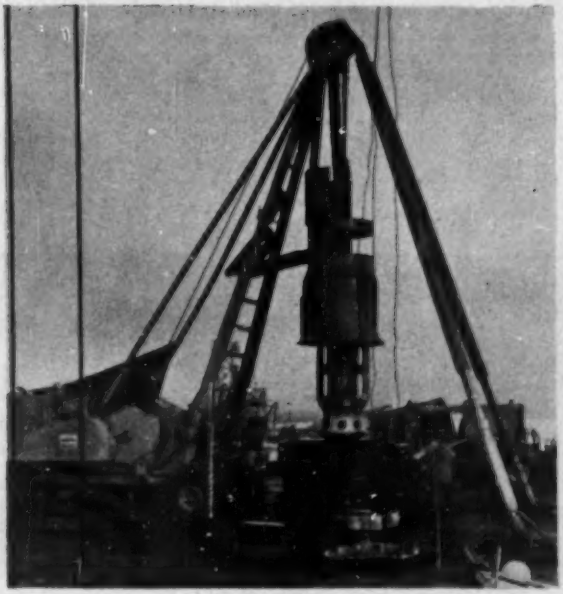

Fig. 8.

The rows are at 30-ft. centres and the three cylinders in each row are 30 ft. and 38 ft. apart respectively. The cylinders, the lengths of which vary from 43 ft. to 67 ft., are made up of precast concrete rings 6 ft. deep and having an external diameter of 6 ft. 3 in. and an internal diameter of 4 ft. 9 in. The rings are cast vertically in steel moulds mounted on bogies, a method which compares favourably with the more usual method of having the moulds in fixed positions. The concrete is compacted by poker vibrators. Ducts for prestressing bars in the cylinders are formed by bright steel tubes which are withdrawn while the concrete is green. The rings are cured in heated sheds and generally are lifted after three days.

At the position of each cylinder, a steel tube with a serrated cutting edge and a wall ⅜ in. thick is pitched by a 15-ton derrick-crane and sunk into the solid marl by the backwards and forwards rotating motion imparted by a Benoto machine. The tubes are extended as sinking proceeds to keep the top above the working platform. Sinking continues until a seal is obtained in the marl, which is usually when the penetration is about 10 ft. Simultaneous with sinking, excavation is carried out within the tube by the Benoto machine operating a hammer-grab (*Fig.* 8) of about 5 ft. diameter, the spoil being discharged into and removed in dumpers. Unlined excavation continues for a further 15 ft. to 25 ft. below the bottom of the tube as shown diagrammatically at B in *Fig.* 6. At intervals the diameter of the cavity is increased from 5 ft. to 6 ft. 9 in. diameter by the cutting tool (*Fig.* 9) being operated by the grabbing machine. A concrete pad is constructed within the tube at the level of the foundation, and on it the precast concrete rings, each of which weighs about 6 tons, are placed as shown diagrammatically at C in *Fig.* 6. Initially the joints between the rings were caulked with earth-dry concrete, but an improved joint of comparable strength is now produced by using a sand-cement mortar containing an admixture to accelerate the setting.

Fig. 9.

When all the rings for a cylinder are in position, ¾-in.-diameter high-tensile steel bars are inserted in the ducts in the walls of the rings. Previously the bars are brushed clean and are then wrapped in protective tape. For these operations the bars are supported waist-high on steel

Fig. 10.

Fig. 11.

trestles (*Fig.* 10). The upper ends of the bars for one cylinder are then secured to a circular steel template (*Fig.* 11) which ensures the bars are in the correct positions to suit the ducts in the wall of the cylinder. The template is lifted by the derrick-crane so that the bars hang vertically (*Fig.* 12) and can be lowered into the ducts in the rings. This operation is shown diagrammatically at A in *Fig.* 6. The lower ends of the bars are secured by nuts which are screwed on through openings provided in the bottom ring.

The rings forming one cylinder are now pulled together by tensioning the bars. Each front and central cylinder contains six bars and each rear cylinder eighteen bars. After grouting the ducts, the cylinders are sealed at the bottom by a plug of colloidal concrete and are filled with lean concrete and sand.

The rear and central cylinders are surmounted by a cast-insitu reinforced concrete cap which is cast in a steel mould (*Fig.* 13). The front cylinders are surmounted by the large concrete fender-blocks, the prestressing bars extending from the cylinders up through the fender-blocks by the use of couplers. Stressing is carried out from the tops of the fender-blocks. The substructure of the round-head is constructed similarly but in this case the cylinders are in rows of four.

Upon completion of the construction of the cylinders, the steel tube is extracted by a machine fitted with hydraulic jacks of 60 tons capacity. As the tube is withdrawn, the annular void between the concrete cylinder and the excavation is filled with sand-cement grout injected through pipes extending from the platform.

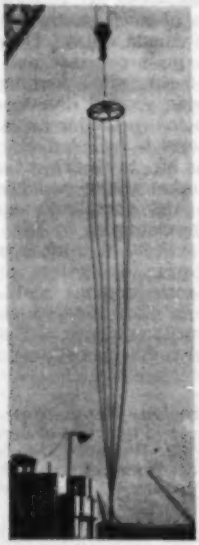

Fig. 12.

Fig. 13.

The consulting engineers for Quay No. 1 are Sir William Halcrow & Partners, who, for the prestressed concrete superstructure, are assisted by Messrs. A. J. & J. D. Harris. The preliminary site investigation was carried out by Messrs. Le Grande Sutcliffe & Gell. The contractors are The Demolition & Construction Co., Ltd. The steel moulds for the cylinder caps were supplied by Stelmo Ltd. The bars, anchorages and jacks for prestressing the cylinders were supplied by McCalls Mcalloy Ltd. The quay is being constructed for the Tees Conservancy Commissioners.

The construction of the superstructure will be described in a subsequent article.

Book Reviews.

"Deep Foundations and Sheet-piling." By D. H. Lee. (London: Concrete Publications Ltd. 1961. Price 20s.)

"Design and Construction of Foundations." By G. P. Manning. (London: Concrete Publications Ltd. 1961. Price 24s.)

Mr. Donovan Lee's book "Sheet Piling, Cofferdans and Caissons" enjoyed an active life of almost fifteen years. His new book incorporates much that was in the earlier publication, but brought up to date where necessary, and includes so much new matter that it is comprehensive as regards the subject of foundations on strata some distance below ground. With modesty, the author has chosen to call it "an introduction" to the study of the design and construction of deep foundations since he maintains that so vast a subject cannot be dealt with completely in some two hundred and fifty pages; some aspects must be omitted or treated superficially. Nevertheless, the consideration given to sheet-pile walls, cofferdams, cylinders and caissons is sufficiently detailed for a practising civil engineer, to whom the book is primarily addressed, to acquire data and knowledge of other engineers' experience in these specialised fields. Such a subject as soil mechanics is dealt with summarily because this book does not claim to be a treatise on that subject, and only as much as is essential is given, and that little is in a form of reminders rather than in text-book style. The author's views on the bearing capacity of driven piles make informative reading. Students and young engineers, although not likely to be required to design deep foundations in their early years, will, however, gain much by a study of this work as it gives a good picture of the practical difficulties, and how they are overcome, which confront a civil engineer when dealing with ground or water or the two elements in combination. The examples of actual works are drawn from all parts of the world and some floating caissons and subaqueous tunnels are described. The bibliographical references are extensive.

Mr. Manning's book is mainly complementary to Mr. Lee's since it deals almost entirely with foundations at shallow depths. It is a book, as the author claims, that is most suitable for the civil engineer who is called upon to design the type of foundation normally required and to do so without calling upon a specialist for advice. One of the best chapters in the book is that on raft foundations which are considered with a minimum of mathematics and a maximum of common sense. Other chapters deal with mass concrete and reinforced concrete bases, piled foundations, submerged sites, ground investigations, and constructional procedures. A series of design charts is included.

Whereas Mr. Lee's subject necessitates drawing upon the experience of many engineers, the completely worked and illustrated examples in Mr. Manning's book are entirely of work carried out by himself during a lifetime of practice. The numerous axioms and statements arising from clear independent thinking should benefit students and should even cause older engineers to pause to re-assess some established ideas.

Betonkorrosion—Betonschutz. (Corrosion of Concrete—Protection of Concrete.) By Imre Bicsók. [Budapest: Akadémiai Kiadó (Publishing House of the Hungarian Academy of Sciences). 1960. Price 7.00 dollars.]

The purpose of this book (which is the German translation of the revised edition

of an Hungarian book first published in 1955) is to survey the problems involved in protecting concrete from corrosion and the present knowledge on this subject. It is based on a thorough study of English, American, French, German, Russian, Czechoslovakian and Hungarian literature up to 1957 and includes the author's own experience. The bibliography contains over three hundred entries. An English edition of this book would be useful.

The book is in five chapters, the first of which deals with the components of concrete, that is, cement, aggregate and water, from the point of view of their resistance to corrosion. The greater part of this chapter is devoted to the chemistry of cement, and the advantages and disadvantages of the various types of cement are described. It is of interest to note that a Hungarian high-alumina cement, which had a high reputation far beyond Hungary as being particularly suitable where resistance to the corrosive action of sulphates was required, is no longer manufactured, it having been found that concrete made with this cement disintegrates if exposed to warm water or steam for a long period. The roof of a swimming pool for which this cement was used was attacked by steam to such an extent that it had to be demolished and re-built with Portland-cement concrete. In the second chapter the investigation of ground and of ground-water is considered and the importance of seasonal variations of the chemical composition of the ground-water is emphasised.

In the third chapter, the various causes of corrosion and the results of research are described. Corrosion may be caused not only by water containing harmful substances but also by soft or chemically pure water such as distilled water or water obtained by industrial condensation. Recommendations are made for the protection of concrete against various types of attack and the regulations in Germany, U.S.A., Czechoslovakia, U.S.S.R., Britain and; Hungary are critically reviewed. The author points out that the recommendations of B.R.S. Digest No. 31 are unique in so far that they relate not only to the aggressiveness of the ground-water but also of the soil and, in contrast to all other regulations, they take into account the expected life of the structure. A method of protecting the reinforcement, which has been used successfully in the U.S.S.R. and in Hungary, is the addition of sodium nitrite ($NaNO_2$) to the mixing water to the extent of 2 to 3 per cent. of the weight of the cement, a method which is hardly known in this country. Experience in Hungary has shown that the addition of sodium nitrite to the mixing water has a favourable effect on the strength of the concrete. The factors which may influence corrosion, such as the flow of the ground-water, its change of temperature and level, the thickness of the concrete member, and exposure to air, are discussed in the fourth chapter.

The last chapter contains a summary of protective measures, some of which are described in detail and illustrated by examples.—H.-K.

"Frame Analysis." By A. S. Hall and R. W. Woodhead. (London: John Wiley & Sons Ltd. 1961. Price 68s.)

THE introduction of electronic computers to assist structural analysis has made it possible to analyse framed structures of a complexity that, for economic reasons, was hitherto impractical. The solution of these problems is facilitated by the use of more flexible methods than those, such as moment distribution, which had been developed because of their suitability in solving particular types of problem. Although the application of computers is not specifically mentioned in this book, it is implicit in many of the solutions described. It sets out particularly clearly the alternative general approaches to analysis by stiffness or flexibility methods and considers, in particular, the methods of slope-deflection and influence coefficients as examples of these. In addition to the more common lengthy mathematical analysis, matrix algebra is extensively used. The theory of matrices necessary for a complete understanding of the text is also included in an appendix.

"Principles of Structural Design." By Niels Lisborg. (London: B. T. Batsford Ltd. 1961. Price 30s.)

ACCORDING to the preface, this book sets out to provide a "panoramic view of the whole subject" of structural design. The terms in which it does so are intended to be of value to engineers and architects, and accordingly the treatment is more general than that normally adopted in engineering text-books. The first part of the book deals with structural principles,

and includes some thirty pages on the theory of reinforced concrete. A second section contains tabulated data for design in steel, timber, plain and reinforced concrete and masonry in accordance with the relevant British Standards and codes of practice. The work is completed by a section containing mathematical data and examples of simple structural calculations. Of particular interest are those examples where, for specified loadings, comparative designs in timber, reinforced concrete and steel are prepared.

It is natural in a work of such wide scope that the treatment of some aspects should be somewhat superficial. However, without qualification some of the categorical statements made in the text, for example, that regarding the alternative merits of stirrups and inclined bars as shearing reinforcement, are open to question.

" Schubsicherung bei Spannbeton ohne Schubbewehrung." By Hubert Rusch and Gunnar Vigerust. (Berlin: Wilhelm Ernst & Son. 1960. DM. 11.)

In the two parts of this publication the authors deal with the shearing strength of prestressed concrete beams without web reinforcement. The shearing strength of prestressed beams is not generally governed by the shearing stress, but by the principal tensile stresses to which the shearing stresses contribute. At working loads the principal tensile stresses are generally small and are not a criterion of the available shearing strength, which should be derived from the ultimate shearing load. The authors are of the opinion therefore that the determination of the principal tensile stresses as provided for in German Code of Practice DIN 4227 could be omitted. It is considered that the load which causes wide inclined cracks due to shearing can be best expressed in terms of a bending moment, a suggestion which appears to be confirmed by the results of tests carried out by American research workers. The formula proposed by the author for this moment takes into consideration the influence of the prestress, the amount of longitudinal reinforcement, the quality of the concrete, and the geometry of the section.

The design for resistance to shearing requires a larger factor of safety than that for bending, because shearing cracks often develop suddenly and lead to immediate failure of the beam. Because present knowledge of shearing stresses in prestressed beams is limited, the authors suggest that a factor of 2·6 should be adopted. The calculation of the shearing stress should always be made for the " critical " section in bending, which, for a freely-supported beam with a concentrated load, is at the point of application of the load. If the load is uniformly distributed it is suggested that the critical moment is that at the centre of the span. The authors consider that suitable links should be provided to limit shearing cracks.

" Beton-Kalendar 1961 (Parts I and II)." (Berlin: Wilhelm Ernst & Son. 1961. Two volumes. DM. 20.)

In the jubilee number of this well-known handbook, the chapter on geometry has been omitted and the chapter on structural analysis severely curtailed in order to reduce the size of the volumes and yet to include most of the many developments which have taken place during the past five years. Additional matter includes the calculation of rectangular slabs supported on three edges and carrying uniformly-distributed and triangularly-distributed loads. Machine foundations and other structures subject to vibration and comments on the Swiss reinforced concrete regulations are also included. The chapters dealing with foundations, stairs, floors and applications of prestressed concrete have been revised.

" Building Technician's Pocket Diary, 1962." (London: Association of Building Technicians. Price 6*s.* 7*d.*)

This is the forty-first issue of a useful pocket book containing about 170 pages of data and general information. There are at least thirty pages containing matter of direct interest to concrete engineers.

Bulletins Received.

" The Performance of Compaction Plant in the Compaction of Two Types of Granular Base Material." (London: H.M.S.O. 1961. Road Research Laboratory. Price 2*s.* 3*d.*)

" Rock Mechanics." (London: Soil Mechanics Ltd. 1961. No price stated.)

" Plastics in Building." (Welwyn Garden City: Imperial Chemical Industries Ltd., Great Britain. 1961. No price stated.)

Forces in Three-dimensional Groups of Piles.—II.*

By W. E. SCRIVEN, B.Sc. (Eng.).

Examples of Circular Groups.

EXAMPLE NO. 1.—Suppose that there are N node points on a circle of radius a and that at each node point there are two piles with the same values of μ and horizontal angles of $+\phi$ and $-\phi$ (*Fig.* 6). (Note that μ is the angle indicated by the symbol η in Fig. 5 in the preceding part of this article.)

Then $v = \dfrac{P_y}{N \sin^2 \mu}$; $w = \dfrac{P_z}{2N \cos^2 \mu}$; and $\alpha = \dfrac{M_x}{a^2 N \cos^2 \mu \sin^2 \phi}$;

hence from equation (7),

$$F_\theta = \frac{P_y . \cos(\theta + \phi)}{N \sin \mu} - \frac{P_z}{2N \cos \mu} - \frac{M_x . \sin(\theta + \phi)}{aN \cos \mu \sin \phi} \quad . \quad . \quad (16)$$

To find the greatest and least values, $\dfrac{\partial F_\theta}{\partial \theta} = 0$

and $$- P_y \frac{\sin(\theta + \phi)}{N \sin \mu} - \frac{M_x \cos(\theta + \phi)}{aN \cos \mu \sin \phi} = 0.$$

Therefore $$\tan(\theta + \phi) = - \frac{M_x \sin \mu}{aP_y \cos \mu \sin \phi} = - \frac{M_x}{aP_y} \tan \mu \operatorname{cosec} \phi$$

Substituting $k = - \dfrac{M_x}{aP_y}$,

$$\tan(\theta + \phi) = k \tan \mu \operatorname{cosec} \phi \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Substituting equation (17) in equation (16) gives:

$$F_{\theta_{\substack{\text{max.} \\ \text{min.}}}} = \pm \frac{P_y}{N \sin \mu} \sqrt{1 + k^2 \tan^2 \mu \operatorname{cosec}^2 \phi} - \frac{P_z}{2N \cos \mu} \quad . \quad . \quad (18)$$

For the particular case of a tower supported on raking piles, let W be the weight of the tower and H the resultant wind force acting at a height h above the pile-cap; then

$$W = - P_z; \quad H = P_y; \quad \text{and} \quad M_x = - H(h - z_0) = + H(a \cot \mu \cos \phi - h).$$

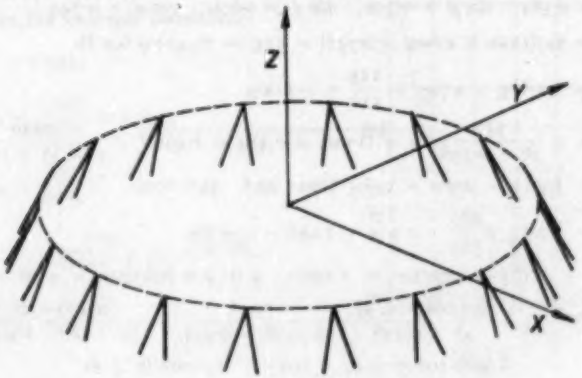

Fig. 6.

* *Continued from November 1961.*

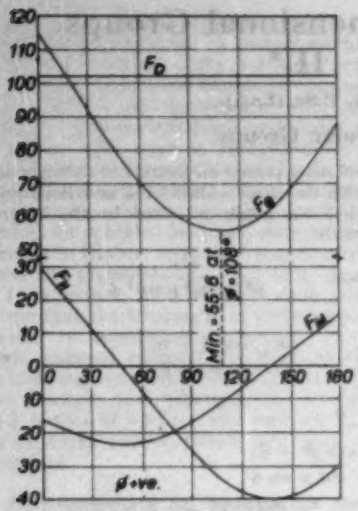

Fig. 7.

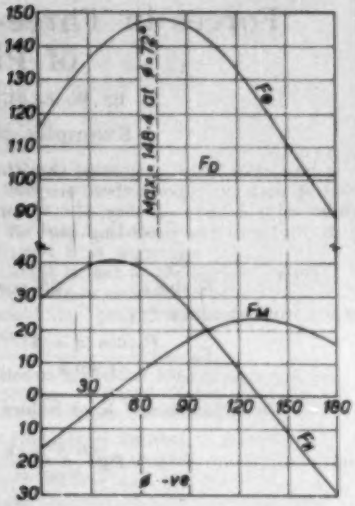

Fig. 8.

Hence $$k = -\frac{M_x}{P_y a} = -\frac{H(a\cot\mu\cos\phi - h)}{Ha} = -\cot\mu\cos\phi + \frac{h}{a};$$

$$F_\theta = \pm\frac{H}{N\sin\mu}\sqrt{1 + h^2\tan^2\mu\,\mathrm{cosec}^2\phi} + \frac{W}{2N\cos\mu} \quad . \quad . \quad (19)$$

and $$\tan(\theta + \phi) = -\cot\phi + \frac{h}{a}\tan\mu.\mathrm{cosec}\,\phi \quad . \quad . \quad . \quad (20)$$

For example, if $W = 7240$ tons; $H = 547$ tons; $a = 132$ ft.; $h = 123$ ft.; $N = 38$; $\mu = 21°$; and $\phi = 42°$; then

$$\tan\mu = 0{\cdot}384; \quad \sin\mu = 0{\cdot}358; \quad \sin\phi = 0{\cdot}670; \quad \cos\phi = 0{\cdot}743.$$

$$M_x = 547[(132 \times 2{\cdot}605 \times 0{\cdot}743) - 123] = 72{,}470{\cdot}9 \text{ ton-ft.}$$

$$h = -2{\cdot}605 \times 0{\cdot}743 + \frac{123}{132} = -1{\cdot}005.$$

$$F_\theta = \pm\frac{547}{38 \times 0{\cdot}358}\sqrt{1 + (1{\cdot}005 \times 0{\cdot}384 \times 1{\cdot}491)^2} + \frac{7240}{2 \times 38 \times 0{\cdot}934}$$

$$= \pm 46{\cdot}4 + 102{\cdot}0 = 148{\cdot}4 \text{ tons} \quad \text{and} \quad 55{\cdot}6 \text{ tons.}$$

$$\tan(\theta + \phi) = \mp 1{\cdot}11 \pm\frac{123}{132} \times 0{\cdot}384 \times 1{\cdot}491 = \pm 0{\cdot}576.$$

$\theta = +30° + \phi$ (if ϕ is negative) or $+150° - \phi$ (if ϕ is positive) $= +72°$ or $+108°$.

Generally $$F_\theta = \frac{547\cos(\theta \pm \phi)}{38 \times 0{\cdot}358} + \frac{7240}{2 \times 38 \times 0{\cdot}934} \mp \frac{72{,}470{\cdot}9\sin(\theta \pm \phi)}{132 \times 38 \times 0{\cdot}934 \times 0{\cdot}670}$$

$$= 40{\cdot}2\cos(\theta \pm \phi) + 102{\cdot}0 \mp 23{\cdot}1\sin(\theta \pm \phi).$$

Figs. 7 and 8 show the distribution of forces with respect to θ.

$F_H = 40{\cdot}2\cos(\theta \pm \phi)$, $F_D = 102{\cdot}0$, and $F_M = 23{\cdot}1\sin(\theta \pm \phi)$.

The foregoing enables the loads in any given arrangement to be found. If it is required to find the system that will give the least pile loading, the maximum force in any pile is given by

$$F = \frac{W}{2N\cos\mu} + \frac{H}{N\sin\mu}\sqrt{1 + k^2\tan^2\mu\,\mathrm{cosec}^2\,\phi}.$$

Assume that the value of ϕ is fixed; then by equating $\frac{\partial F}{\partial \mu}$ to zero the optimum value of μ can be found, as follows.

$$\frac{\partial F}{\partial \mu} = \frac{W}{2N}\sec\mu.\tan\mu + \frac{H}{N}\left\{-\mathrm{cosec}\,\mu.\cot\mu\sqrt{K} + \mathrm{cosec}\,\mu\frac{1}{2\sqrt{K}}.2k_0^2\tan\mu.\sec^2\mu\right\}$$

in which $\sqrt{K} = \sqrt{1 + k_0^2\tan^2\mu}$ and $k_0 = k\,\mathrm{cosec}\,\phi$; k is here regarded as positive, since it is the implied root of k^2.

Putting $\frac{\partial F}{\partial \mu} = 0$, and simplifying, $\frac{W}{2H}\tan^2\mu\sqrt{K} + k_0^2\tan^4\mu - 1 = 0$.

$$\text{If } n^2 = 1 + k_0^2\tan^2\mu, \tan\mu = \sqrt{\frac{n^2-1}{k_0^2}};$$

hence

$$\frac{W}{2Hk_0}.n^4\left(1 - \frac{1}{n^2}\right)^{\frac{1}{2}} + (n^2-1)^2 - k_0^2 = 0.$$

(Note that n in this context is not to be confused with the directional cosine n in the preceding part.)

Let $k_1 = \frac{W}{4Hk_0}$, and since $n^2 > 1$, then expansion by the binomial theorem gives

$$2k_1.n^4\left(1 - \frac{3}{2n^2} + \frac{3}{8n^4} - \ldots, \text{etc.}\right) + n^4 - 2n^2 + 1 - k_0^2 = 0.$$

Hence $n^2 = \{3k_1 + 2 \pm \sqrt{(3k_1+2)^2 - (2k_1+1)(3k_1+4-4k_0^2)}\}\frac{1}{2(2k_1+1)}$

and

$$\tan^2\mu = \frac{\sqrt{k_1(3k_1+1) + 4k_0^2(2k_1+1)} - k_1}{2k_0^2(2k_1+1)} \quad . \quad . \quad . \quad (21)$$

For the example considered

$k = 1{\cdot}005$;

$$k_0 = \frac{1{\cdot}005}{0{\cdot}670} = 1{\cdot}500;$$

$$k_1 = \frac{W}{4Hk_0} = \frac{7240}{4 \times 547 \times 1{\cdot}5} = 2{\cdot}205.$$

Therefore

$$\tan^2\mu = \frac{\sqrt{2{\cdot}205 \times 7{\cdot}615 + 4 \times 2{\cdot}25 \times 5{\cdot}41} - 2{\cdot}205}{24{\cdot}345} = 0{\cdot}241, \text{ and } \mu = 26{\cdot}1°.$$

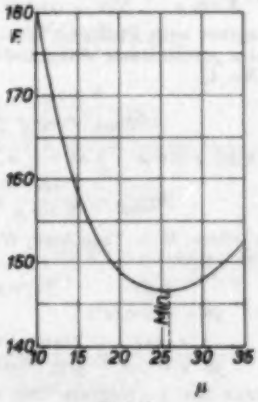

Fig. 9.

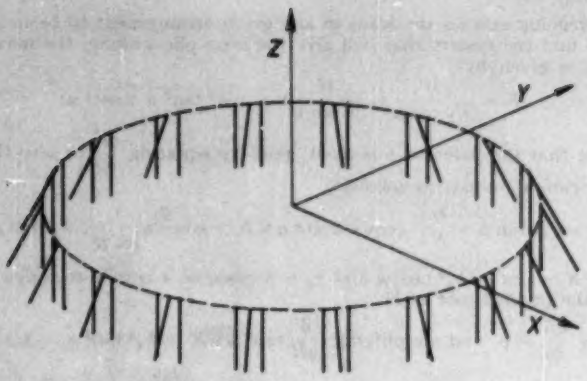

Fig. 10.

The relation between μ and F is shown in *Fig.* 9.

EXAMPLE No. 2.—Suppose that at each node point on a circle of radius a there are two vertical piles and one radial pile at a vertical angle μ (*Fig.* 10). For vertical piles $\mu = 0$, $\phi = \frac{\pi}{2}$; for inclined piles $\mu = \mu$, $\phi = 0$; $z_0 = a \cot \mu$.

For vertical piles

$$F_V = -\frac{P_z}{N(2 + \cos^2 \mu)} - \frac{2M_x \cos \theta}{2aN} = -\frac{P_z}{N(2 + \cos^2 \mu)} - \frac{M_x \cos \theta}{aN}.$$

For inclined piles

$$F_I = \frac{2P_y \sin \mu \cos \theta}{N \sin^2 \mu} - \frac{P_z \cos \mu}{N(2 + \cos^2 \mu)} + \frac{M_x}{aN}\{-a \cos \mu \cos \theta + a \cos \mu \cos \theta\}$$

$$= \frac{2P_y \cos \theta}{N \sin \mu} - \frac{P_z \cos \mu}{N(2 + \cos^2 \mu)}.$$

This agrees with Professor Westergaard's conclusion that piles with centre-lines meeting at a point cannot withstand an overturning moment. Using the notation of Example No. 1,

$$F_{V_{max.}} = \frac{W}{N(2 + \cos^2 \mu)} \pm \frac{H(a \cot \mu - h)}{aN},$$

provided that $a \cot \mu > h$ at $\theta = \pi$, $a \cot \mu < h$ at $\theta = 0$,

and $$F_{I_{max.}} = \frac{2H}{N \sin \mu} \pm \frac{W \cos \mu}{N(2 + \cos^2 \mu)} \text{ at } \theta = 0.$$

If, as before, $W = 7240$ tons; $H = 547$ tons; $a = 132$ ft.; $h = 123$ ft.; $N = 38$; and $\mu = 21°$, then

$$F_{V_{max.}} = \frac{7240}{38(2 + 0{\cdot}934^2)} + \frac{547(132 \times 2{\cdot}60 - 123)}{132 \times 38} = 66{\cdot}4 + 24{\cdot}0 = 90{\cdot}4 \text{ tons.}$$

$$F_{I_{max.}} = \frac{2 \times 547}{38 \times 0{\cdot}358} + \frac{7240 \times 0{\cdot}934}{38(2 + 0{\cdot}934^2)} = 80{\cdot}5 + 62{\cdot}0 = 142{\cdot}5 \text{ tons.}$$

EXAMPLE No. 3.—Suppose that the piles are arranged in three concentric circles (*Fig.* 11). In the outermost circle there are two raked piles at each of 12 nodes, at angles of $+\phi$ and $-\phi$, μ being common to both. All piles have the same value of ϕ.

For the vertical piles $\mu = 0$; $\phi = \frac{\pi}{2}$. From equation (14), $z_0 = 3a \cot \mu \cos \phi$.

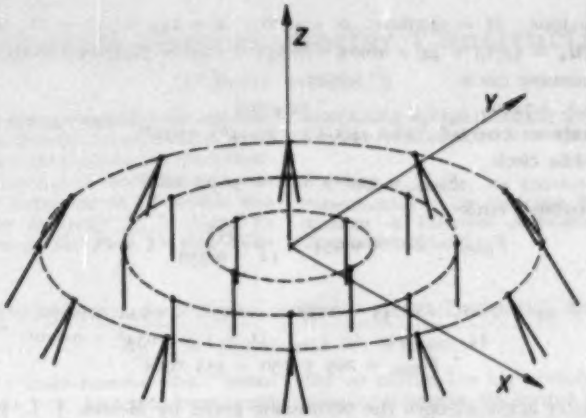

Fig. 11.

$$v = 2P_y \times \frac{1}{4 \times 0 + 8 \times 0 + 12 \times 2\sin^2\mu} = \frac{P_y}{12\sin^2\mu};$$

$$w = P_z \times \frac{1}{4 \times 1 + 8 \times 1 + 12 \times 2\cos^2\mu} = \frac{P_z}{12(1 + 2\cos^2\mu)};$$

$$\alpha = M_x \times \frac{1}{a^2 \times 4 \times 1 + (2a)^2 \times 8 \times 1 + (3a)^2 \times 12\cos^2\mu\sin^2\phi} = \frac{M_x}{18(1 + 3\cos^2\mu\sin^2\phi)a^2}.$$

For the innermost circle

$$F = -\frac{P_z}{12(1 + 2\cos^2\mu)} - \frac{M_x\cos\theta}{18a(1 + 3\cos^2\mu\sin^2\phi)}.$$

If M_x is positive, the maximum value of F occurs at $\theta = \pi$; if M_x is negative, the maximum occurs at $\theta = 0$. Hence assuming that P_z is negative and using the notation of Example No. 1,

$$F_{max.} = \frac{W}{12(1 + 2\cos^2\mu)} \pm \frac{H(z_0 - h)}{18a(1 + 3\cos^2\mu\sin^2\phi)}.$$

For the middle circle

$$F = -\frac{P_z}{12(1 + 2\cos^2\mu)} - \frac{M_x\cos\theta}{9a(1 + 3\cos^2\mu\sin^2\phi)}.$$

The conditions for locating the maximum value of F are as before and

$$F_{max.} = \frac{W}{12(1 + 2\cos^2\mu)} \pm \frac{H(z_0 - h)}{9a(1 + 3\cos^2\mu\sin^2\phi)}.$$

For the outermost circle

$$F = \frac{P_y\cos(\theta + \phi)}{12\sin\mu} - \frac{P_z\cos\mu}{12(1 + 2\cos^2\mu)} - \frac{M_x\sin\phi\cos\mu\sin(\theta + \phi)}{6a(1 + 3\cos^2\mu\sin^2\phi)}.$$

For F to be a maximum or minimum, $\frac{\partial F}{\partial\theta} = 0$.

Therefore

$$\tan(\theta + \phi) = t = -\frac{2M_x}{aP_y} \cdot \frac{\sin\mu\cos\mu\sin\phi}{(1 + 3\cos^2\mu\sin^2\phi)} = -\frac{2(z_0 - h)}{a} \cdot \frac{\sin\mu\cos\mu\sin\phi}{(1 + 3\cos^2\mu\sin^2\phi)}$$

and

$$F_{\substack{max. \\ min.}} = \pm\frac{W}{12\sin\mu}\sqrt{1 + t^2} + \frac{W\cos\mu}{12(1 + 2\cos^2\mu)}.$$

If $W = 7240$ tons; $H = 547$ tons; $a = 44$ ft.; $h = 123$ ft.; $y = 21°$ and $\phi = 42°$,

$$M_s = 547(3 \times 44 \times 2{\cdot}605 \times 0{\cdot}743 - 123) = 72{,}470{\cdot}9 \text{ ton-ft.}$$

For the innermost circle

$$F_{max.} = \frac{7240}{12(1+2\times0{\cdot}934^2)} + \frac{72{,}470{\cdot}9}{18\times44(1+3\times0{\cdot}934^2\times0{\cdot}670^2)} = 220+42{\cdot}1 = 262{\cdot}1 \text{ tons;}$$

For the middle circle

$$F_{max.} = 220 + 84{\cdot}2 = 304{\cdot}2 \text{ tons.}$$

For the outermost circle

$$F_{max.} = 220 \times 0{\cdot}934 + \frac{547}{12 \times 0{\cdot}358}\sqrt{1+t^2},$$

in which

$$t = -\frac{2(3 \times 44 \times 2{\cdot}605 \times 0{\cdot}743 - 123)}{44} \times \frac{0{\cdot}358 \times 0{\cdot}934 \times 0{\cdot}670}{(1+3\times0{\cdot}934^2\times0{\cdot}670^2)} = -0{\cdot}62.$$

Hence $$F_{max.} = 205 + 150 = 355 \text{ tons.}$$

The writer acknowledges the permission given by Messrs. J. L. Kier & Co., Ltd., for him to prepare and publish this series of articles.

"Concrete and Constructional Engineering" Prize Designs.

THERE were about fifty entries this year for the prize awarded by the proprietors of this journal for competition amongst the students at the post-graduate course of Concrete Technology* at Imperial College, University of London. The project set this year by Professor A. L. L. Baker, D.Sc., M.I.C.E., was the redevelopment of the Billingsgate area of the City of London and the structures to be included in the scheme were warehouses, office buildings, a fish market, a wharf and a bridge across the River Thames. Many of the designs presented were above average standard in conception and presentation. Although, as in previous years, prominence was given to the mathematical aspect of design, especially in the case of the numerous shell roofs offered, there were several designs demonstrating a grasp of the practical side of engineering construction. The detailing was generally good; the students were either experienced or had studied published designs.

In view of the number of good designs of dissimilar structures and the fact that the assessor had difficulty in adjudicating between the best design of a building and the best design of a civil engineering structure such as a bridge, it was decided by the proprietors of this journal to award two prizes of £20 each instead of one prize of £25 as hitherto.

The prize for the best design of an engineering structure was awarded to MR. P. LAINEZ-LOZADA, who presented, in an excellent manner, a design for a prestressed concrete bridge of five equal spans of 160 ft. This design avoided the pitfalls, due to natural hazards of the site, which had been overlooked in some otherwise equally good designs.

The prize for the best design of a building was awarded to MR. G. WILSON for a library. This imaginative structure was of shell construction, elliptical in plan, with ribs extending to the ground in a continuation of the slope of the roof. The calculations were thorough and even included a computer programme.

* See page 433.

Reinforced Cement-mortar Construction.

("Ferro-cement")

Two recent and quite different applications, in the British Isles, of reinforced cement mortar are described in the following. The material in both instances is similar to "ferro-cement" * which was developed by Professor P. L. Nervi in Italy, and is in the form of thin slabs comprising a high-strength dense cement mortar reinforced with a steel mesh.

* "Ferro-cement: Its Characteristics and Potentialities." By Professor P. L. Nervi. (Cement & Concrete Association Library Translation No. 60.)

An Investigation of "Ferro-cement" using Expanded Metal.

By J. G. Byrne and W. Wright.

One of the main reasons why "ferro-cement" has not hitherto been used much outside Italy is undoubtedly the high cost of the woven steel mesh used by Prof. Nervi. To overcome this objection the authors have investigated, at the Engineering School of Trinity College, Dublin, similar material using expanded metal in place of woven steel mesh, because expanded metal is much cheaper. Initially, the investigation was undertaken to verify that the material would be suitable for a roof canopy which has since been constructed; the result of this preliminary research has been published elsewhere,[1] as also has a description of the canopy.[2] The result of further research work is reported in the following.

The Mortar.

In the investigation, a mortar similar to that used by Prof. Nervi was used, except in the case of some shrinkage tests. The cement-sand ratio was 0·7 and the water-cement ratio was 0·4. The cement was rapid-hardening Portland cement of Irish manufacture. An apparently workable mortar was produced, provided that it did not contain too much sand passing a No. 100 B.S. sieve. This mixture is very rich since it contains about 1250 lb. of cement per cubic yard. Consequently, the set mortar has high tensile and compressive strengths, the former being about 500 to 600 lb. per square inch and the latter about 6000 to 7000 lb. per square inch as measured on 4-in. cubes at seven days. Thus it has the desirable property that accompanies high strength, that is, exceptionally high resistance to cracking, but it has a low density of about 133 lb. per cubic foot.

Another advantage of a rich mixture is the high quality of the finished surface. It is difficult to expel all the air from such a mixture by vibration or other means, but tests showed that satisfactory results could be obtained merely by placing the mortar in a mould and that nothing was gained by attempting to compact it further. The mortar was virtually impermeable, as would be expected from the results obtained by Lecznar and Oskroba,[3] who have shown that this is the case if the surface area of the cement is higher than the surface area of the aggregate, as is so with "ferro-cement" mortars. Because of this, "ferro-cement" roofing units are used in Italy without asphalt or other protection, but in the climate prevailing in the British Isles this is not practicable since the durability of the mortar against attrition due to rain and abrasion is not high.

Table I.—Shrinkage of "Ferro-cement".

Water-cement ratio	0·35	0·40	0·40	0·40	0·45	0·50	0·55	0·50	0·55
Cement-sand ratio	Neat	0·70	0·60	0·50	0·40	0·40	0·40	0·33	0·33
Shrinkage	84	71	63	44	57	57	53	47	45

In addition to poor durability, the main disadvantages of the mortar appear to be high shrinkage and creep. Comparative shrinkage tests of 6-in. by 12-in. cylinders were carried out on materials ranging from neat cement to 3 : 1 sand-cement mortars with a water-cement ratio of 0·35. The shrinkage, which was measured on an 8-in. Demec strain-gauge, is given in *Table* I, from which it is clear that the cement-sand ratio has a predominating effect and the water-cement ratio very little effect. For a low water-cement ratio of 0·35 the shrinkage appears to be low despite the high cement content. (The mixture used by Prof. Nervi has a water-cement ratio of 0·35 and is quite workable and plastic if the sand is not too fine.) The sand was very fine and a water-cement ratio of 0·4 gave improved workability and much more shrinkage. No creep tests were carried out, but it generally follows that the same factors affect shrinkage and creep alike. From the point of view of shrinkage and creep only, the best mortar has a water-cement ratio of 0·55 and a cement-sand ratio of 0·33, but these are not necessarily the best ratios from other points of view. The resistance of this mortar to cracking due to shrinkage is about the same as the resistance to cracking of the mortar used in this investigation because of its greater tensile strength. Thus the only undesirable consequences of using a rich mortar are the increased deflections due to shrinkage and creep.

The Steel Mesh.

Prof. Nervi uses a light-gauge square wire-mesh which costs about 2*s*. 4*d*. per lb. in Ireland; expanded metal is about half the price. There are no disadvantages in the use of expanded metal, and there are some advantages such as good mechanical bond, ease of placing and few layers are needed whatever the amount required. It should, however, be noted that during a tensile test with ¼-in. expanded-metal mesh weighing 4·77 lb. per square yard, the mortar split badly due to a scissors action of the diamond mesh, thus indicating that there is a limit to the size and weight of the mesh. A ⅜-in. mesh weighing 1·67 lb. per square yard and a 1-in. mesh up to 2·5 lb. per square yard proved satisfactory. It is difficult to measure the tensile strength of expanded metal in the condition as delivered, but an apparatus (*Fig.* 1) which was devised to measure the tensile strength of "ferro-cement" and which has been described elsewhere[4] proved suitable for measuring the strength of the mesh. The expanded metal is embedded in mortar and a thin piece of cardboard is inserted in the middle; this is easily picked out after the mortar has been cured in water for seven days. The mean tensile strength was found to be 24·6 tons per square inch for clean mesh and 22·4 tons per square inch for steel slightly rusty.

Fig. 1.

The Behaviour of the "Ferro-cement".

"Ferro-cement" behaves in a similar manner to reinforced concrete and the strength of members is calculated in the same way. The fact that a light, well-distributed mesh is used gives some advantages over ordinary reinforced concrete in that the widths of the cracks are much less and the distribution of the cracks more favourable. This helps to counteract the adverse effect the small cover of mortar might have on the corrosion of the steel, which is generally thought to be the main disadvantage of "ferro-cement". Tests carried out by Miss R. Friedland[5] show that the most important factor in the protection of the steel is a dense plastic cement paste of good quality. The cover has an effect only when the quality of the cement paste is not good, that is, when there is too little cement, too much water and insufficient compaction. This

is therefore a good reason for using a rich mortar such as used by Prof. Nervi.

The main criterion in the design of structures containing light thin elements is the limitation of deflection due to shrinkage and creep. An advantage of the mesh is that deflections due to shrinkage are reduced, since the mesh is distributed in a reasonably uniform manner. Two specimens, each 2 in. by 4 in. by ¾ in., were tested under half the cracking load; one had two layers of mesh and the other had none. The latter specimen deflected 0·023 initially and after two months the deflection was 0·070. The specimen with mesh had a similar initial deflection, but the deflection after two months was 0·095. This larger increase in the case of the reinforced specimen is due to the fact that the steel mesh was placed unsymmetrically, but it is much less than the increase that would be obtained if the reinforcement consisted of a few bars. An unloaded specimen with mesh deflected 0·023. It might be possible to place the mesh in such a way (say, by casting the specimens with the tension side uppermost and ensuring that the centre of gravity of the steel is nearer the compression face) that the deflections due to shrinkage could be reduced considerably. This, in the opinion of the authors, is one of the two main functions of the steel in " ferro-cement " units.

" Ferro-cement " seems to be suitable mainly for small mass-produced precast units which are loaded in compression, and the method of construction used by Prof. Nervi is such that the maximum stresses are not great. It seems to the authors that one way to regard the steel is as providing protection against complete collapse if cracks occur. The ultimate resistance should be regarded as the tensile strength of the mortar for members subjected to tension. Steel equivalent to the cracking load should be provided and, for design purposes, the working load should be taken as equal to half the cracking load. This definition of working stress should ensure that there is no corrosion in favourable atmospheres, and deflection should not be excessive. The most economical method of design might be to consider the working load as equal to the cracking load, thereby making sure that the steel is capable of providing adequate ultimate resistance. The latter method has been employed by the Irish Electricity Supply Board, who have used thin " ferro-cement " slabs in place of steel cover-plates on ducts. The slabs are about 33 in. square and 1 in. thick and have three layers of expanded metal. Four of these slabs were tested and the results were satisfactory; the equivalent uniformly-distributed load at failure over a 29-in. span was 1000 lb. per square foot, which is greater than specified. The deflection at failure was large, being about 1½ in., but this is an advantage since there would be ample visual warning of failure. The working load specified was 150 lb. per square foot, and the initial deflection at this load was about $\frac{1}{1\frac{1}{3}}$ of the span. By placing one layer of steel near the bottom and two near the compression zone, adequate ultimate resistance and considerable reduction of deflection due to shrinkage is ensured.

Apart from doubts about durability, the main objection to " ferro-cement " is probably the cost. The first cost of the material is certainly high, but if an efficient method of construction is used this can be largely overcome. " Ferro-cement " is generally used for small identical units so that only a few accurate

Fig. 2.—Boat with Reinforced Cement-mortar Hull.

(*See page 432.*)

moulds have to be made. Skilled craftsmen are required to make the moulds and also to finish the actual products.

The authors wish to thank Mr. L. D. G. Collen, who initiated the investigation described, and Mr. E. J. Flight, Technical Director of the Expanded Metal Co., for his advice and support.

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(2)—COLLEN, L. D. G. "Some experiments in Design and Construction with Ferrocement." Trans. Inst. C.E. of Ireland, Vol. 86, p. 40.

(3)—LECZNAR and OSKROBA: Nafta (Katowice), No. 7–8, pp. 197–204.

(4)—O'CLERY, D. P. and BYRNE, J. G. "Testing Concrete and Mortar in Tension." Engineering, Vol. 189, 18 March, 1960.

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THE HULL OF A 34-FT. MOTOR CRUISER.

THE construction of concrete boats dates from the very inception of reinforced concrete. It is estimated that between 1917 and 1922 the amount of concrete shipping built on both sides of the Atlantic exceeded 150,000 tons, the vessels ranging in size from 7500-ton oil-tankers to small tugs and lighters. The amount of shipping and other floating structures built during World War II was also considerable. Most of these previous works are of reinforced concrete, but Professor Nervi applied "ferro-cement" to the construction of one or two small craft at the end of the last War. Only recently, however, has the principle of reinforced cement mortar been applied successfully, and on a commercial scale, to the construction of boat hulls. The first boat (*Fig.* 2), the hull of which is of this type of material, was launched in October last. It is a 34-ft. motor cabin-cruiser having a beam of 10 ft. 3 in. and a draft of 2 ft. 6 in. The hull is less than 1 in. thick.

The development of this material for this purpose is the result of collaboration between research workers and a firm of experienced boat builders. Since 1945, much has been learned of the structure of hardened cement paste and this knowledge, combined with investigations carried out at the Imperial College, London, enabled an improved "ferro-cement" to be produced. However, many practical difficulties had to be overcome before the boat builders were able to construct a hull of this material. The builders emphasise that although the principle of construction is relatively simple, very careful control is required at all stages of manufacture if all the difficulties due to shrinkage and creep are to be overcome. Indifferent workmanship could be disastrous.

The hull is cast in one piece, so that there are no joints to form incipient points of leakage or other weakness. There are no interior frames, thereby producing a hull the inside of which is entirely free

Fig. 3.—Hull under construction.

from structural members. The timber templates shown in *Fig.* 3 are those required during construction of the hull. The decks and bulkheads are of mahogany-faced plywood with oak beams supporting the deck and are attached to the hull by means of metal lugs embedded in the shell of the hull. The hull is painted if so required.

It is claimed that a hull made of this material is cheaper than a similar hull made of wood, steel or glass-fibre and is as strong as a steel hull. The weight is about the same as that of a wooden or glass-fibre hull but lighter than a steel hull. It is also claimed that the material possesses a high degree of strength, elasticity and resistance to cracking and impact, besides having the essential property of impermeability and the desirable properties of being proof against corrosion by seawater, resistant to fire, odourless, and less subject to vibration. In the event of damage to a small area, the hull could be repaired with mortar or by adopting the method of repairing glass-fibre hulls.

The notes in the foregoing were contributed by Mr. T. M. Hagenbach of Windboats Ltd., Wroxham, Norfolk, and Mr. K. Newman, B.Sc. (Eng.), A.M.I.C.E., of Concrete Structures and Technology, Imperial College, London. The reinforced cement mortar used in the construction of the hulls is called "Seacrete". Further development is proceeding and includes the construction of three craft with hulls of this material for use on the Norfolk Broads in the 1962 season.

Concrete Structures and Technology Course.

THE one-year post-graduate course on Concrete Structures and Technology at Imperial College, University of London, has now been held for fifteen years. The course is conducted by Professor A. L. L. Baker, D.Sc., M.I.C.E., who reviews the work done during this period as follows.

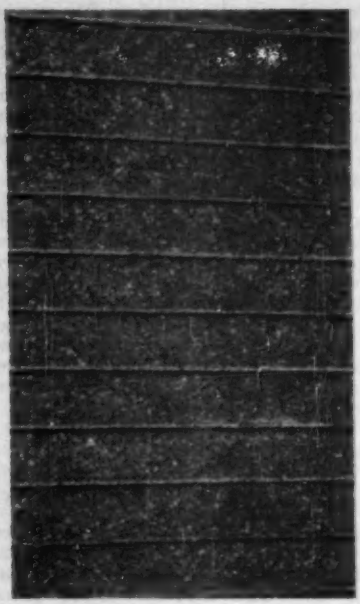
In 1945, many experienced engineers considered that a knowledge of the theory of reinforced concrete design could be acquired best by a student first graduating in engineering science and then working in a design office. It was doubted also whether the study of concrete technology was based sufficiently on engineering science to justify the establishment of a university chair. Experience has removed these doubts. Students from the leading universities of the world now attend this post-graduate course. It is evident that only mature qualified civil engineering graduates are suitable to attend, are able to assimilate the course and to learn advanced structural theory and apply it skilfully. In one year, the intelligent graduate in engineering science is able to become acquainted with a wide range of modern structural theories and to apply them to the design of concrete structures of all kinds, an achievement which would otherwise require many years of evening study and specially organised training in a design office.

The growth of the number of students attending the course from about thirty in 1949 to around sixty in 1960 is described in a brochure entitled "Introductory Note for Donors of Bursaries in Concrete Structures and Technology". The number of applicants is almost three times the number accepted. Particulars of the course, the equipment of the laboratories, and other pertinent information is given in the brochure which is obtainable from Imperial College, South Kensington, London, S.W.7.

A General Equation for Frame Analysis.

THE general and simplified equations allowing for inelastic deformations of statically-indeterminate structures, which were published in an article by Professor Baker in this journal for March and April 1961, were accepted by the European Committee for Concrete at a meeting held in Monaco in January last.

(a)



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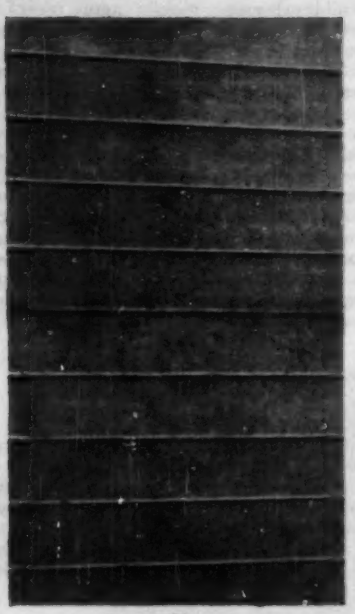

(b)

(d)

Fig. 1.

(*See facing page.*)

Decorative Concrete: Patterned Surfaces.

THIS article is the second in a short series dealing with the architectural treatment of exposed concrete and some types of patterned and moulded surfaces are described. Patterns are produced on the face of concrete walls by forming projections on, or indentations in, the shuttering, or by lining the shuttering with some type of sheeting with a deformed surface, or by facing the wall with precast blocks or slabs of different shapes and textures, or by reproducing the natural markings and joints of the shuttering. (The previous article in this series appeared in the number for October 1961 and dealt with exposed-aggregate surfaces.)

Reproducing Shutter Markings.

Some examples of various ways in which the texture of wooden shutters and the joints between boards can be utilised to relieve a plain wall are shown in *Fig.* 1. A simple pattern can be imparted to the surface of the concrete by ensuring that the joints between the boards are reproduced prominently. It is, of course, essential that the boards should fit tightly to prevent leaking of grout. To give the effect shown in *Fig.* 1a, the shutters were constructed of wrought boards of random thicknesses but each board was 2¾ in. wide. The gravel aggregate contains 37 per cent. of fine material and the cement-aggregate ratio is 1 to 5½; the water-cement ratio was 0·5. An air-entraining agent was incorporated with ordinary Portland cement in the proportion of 60 c.c. of admixture to 1 cwt. of cement.

A more pronounced identification of the joints is shown in *Figs.* 1b and c, in which examples the shuttering was composed of 7-in. by 1¼-in. wrought boards on the edges of which a ¾-in. by ¾-in. chamfer was formed. The chamfer produced on the surface of the concrete a beading ¾ in. wide and ¾ in. deep. The concrete, which was compacted by external vibration using a mechanical hammer, is composed of gravel aggregate comprising equal volumes of fine and coarse materials, and hydrophobic cement. The cement-aggregate ratio is 1 to 5½ and the water-cement ratio was 0·5. The shuttering of the wall in *Fig.* 1b was removed two days after casting and the surface of the concrete was cleaned down with a 5-per-cent. solution of hydrochloric acid twenty-eight days after casting. In the case of the wall in *Fig.* 1c the shuttering was removed one day after casting and the aggregate was exposed by wire-brushing.

An alternative to emphasising the joint-marks is to reproduce the natural markings of the grain of unwrought boards. The shuttering for the wall shown in *Fig.* 1d was formed of 1¼-in. green-sawn boards, 7 in. wide, of Douglas fir. The composition of the concrete is similar to that of the walls in *Figs.* 1b and 1c. The surface was washed down with a 5-per-cent. solution of hydrochloric acid twenty-eight days after casting. It is essential that, when treating with this acid, the surface of the concrete should finally be well washed with clean water to remove all traces of the acid solution.

A similar graining effect is obtained in one of the features of the domestic-training college at Fridhemsplan, near Stockholm, but this structure (*Fig.* 2) is faced with slabs which were precast in wooden moulds the faces of which were deeply grooved to give the pronounced effect of timber graining on the surface of the concrete.

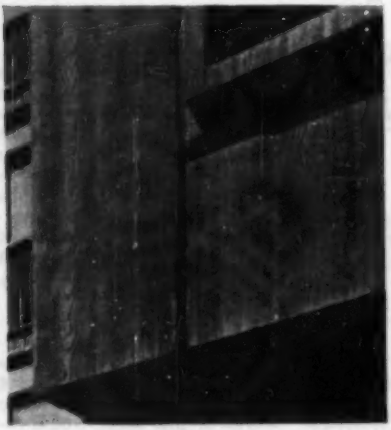

Fig. 2.

Striated Surface.

Striations, similar to graining, but of

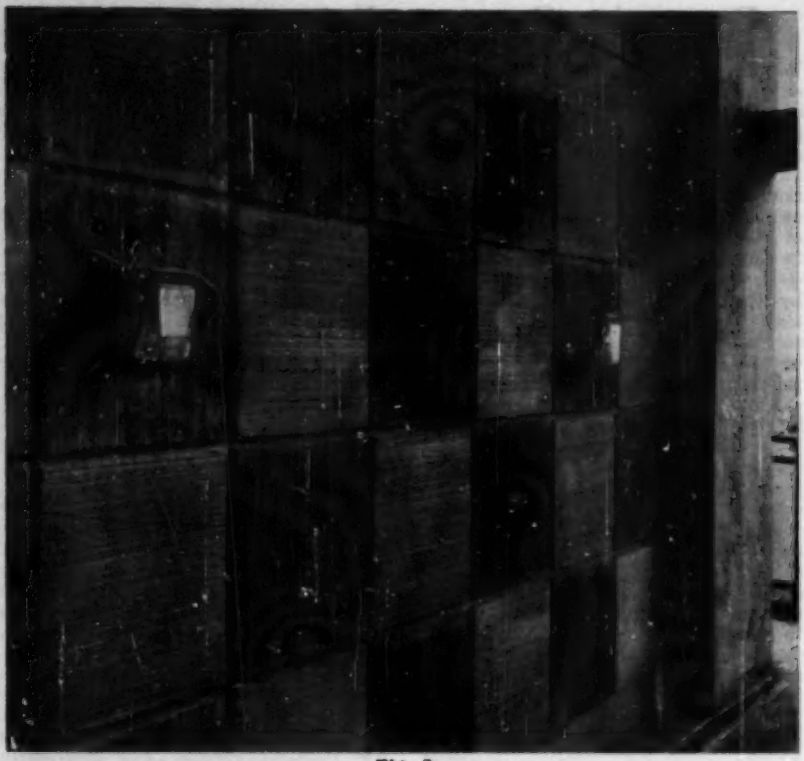

Fig. 3.

more formal pattern, have been produced in other cases, one example being illustrated in *Fig.* 3, which shows the walls of one of the entrance halls of an eleven-storey block of flats erected at the Astley Estate for the Camberwell Borough Council. The structure is such that the loads are carried on reinforced concrete cross-walls which are of monolithic construction. The shuttering comprised 4-in. by 3-in. wooden frames, covered with ¾-in. plywood to which small square sheets of ¾-in. plywood were attached to form the pattern on the face of the concrete. The outer faces of the squares of plywood were striated, or scored, and the sheets were so placed that the striations of adjacent sheets were at right-angles. The chases between the raised panels were formed by a strip of hardwood. The bolts fixing the shuttering were arranged so that they were in the chases and it was therefore possible to conceal the bolt-holes upon completion of the wall. A mesh of chicken-wire was attached to the vertical reinforcement bars in the wall to prevent the immersion vibrators from damaging the striations in the plywood. The concrete in the walls was placed in one lift for each storey-height of about 8 ft. The compaction of the concrete had to be of a high standard as it was impracticable to make good any faulty areas of the surface.

Engraved Shutters.

More elaborate designs of surface markings are obtained by engraving or carving the pattern (in reverse) in the face of the shutters. Works of this kind, which require the services of an artist, have been

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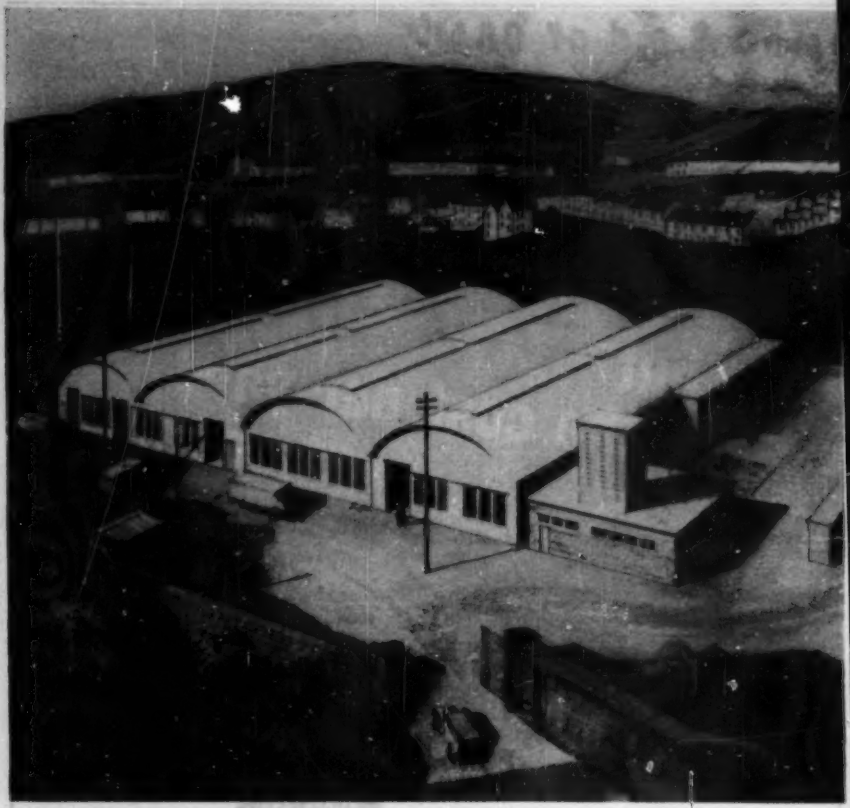

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Fig. 4.

incorporated in several buildings erected by the London County Council. A typical example is that shown in *Fig.* 4, the design for which was carved in chipboard. The wall is cast in concrete comprising 1 part of Portland cement of buff colour and 6 parts of ¾-in. graded gravel aggregate comprising 40 per cent. of sand.

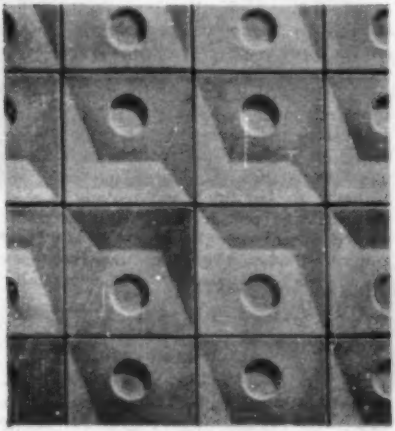


Fig. 5.

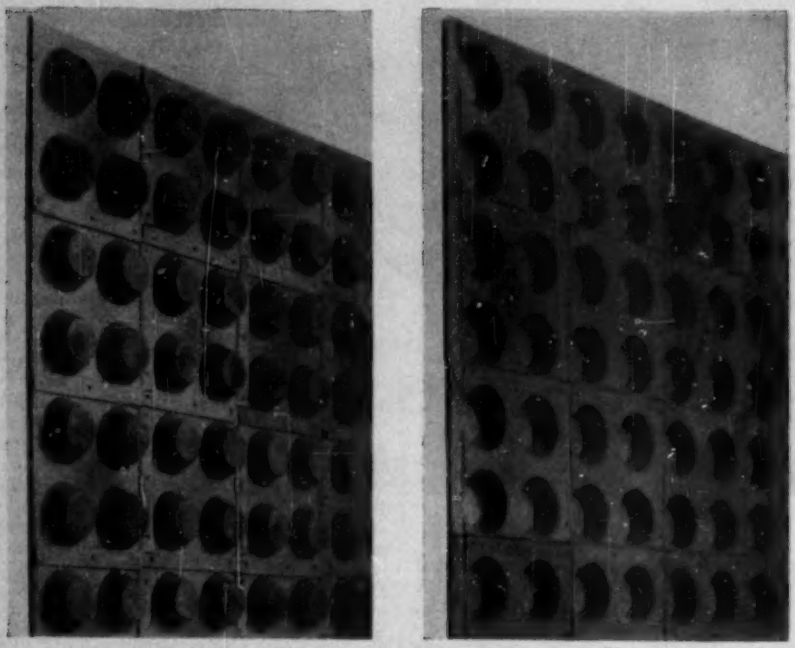
Shutter Linings.

It has been the practice for many decades to obtain simple patterned surfaces on cast-insitu concrete walls by inserting in the shuttering liners of various shapes and textures. Such linings may be strips of wood, corrugated sheets, or mouldings of plaster, mortar or concrete. More recently linings of plastic and, in a few cases, rubber and other materials have been used.

Plastic linings produce a remarkably dense and semi-glazed egg-shell surface to concrete which has been suitably proportioned. The plastic material may be thermoplastic, vinyl or polystyrene. A pattern, on the surface of which the design is formed, is required and it may be of wood, mortar, plaster, glass or other material. The sheet of plastic, heated to a temperature exceeding 300 deg. F., is pressed down on to the pattern. Any slight imperfections in the surface of the pattern are not necessarily reproduced in the concrete since the concrete is cast against the face of the plastic lining which was not in contact with the pattern. Plastic linings do not require the use of a mould oil and are available in panels up to 6 ft. by 4 ft. It is said that they can be used up to eighty times.

The example in *Fig.* 5 is of a specimen wall constructed of standard patterned blocks cast in moulds having thermoplastic linings. A variety of designs can be produced by various arrangements of standard blocks. The slabs in *Fig.* 6

Fig. 6.



(a) (b)

Fig. 7.

were cast similarly, but the concrete is of the quality commonly used for cast stone. The slabs were designed by the Schools Division of the London County Council, slabs of this type being used on the St. Magnus's School, Sydenham.

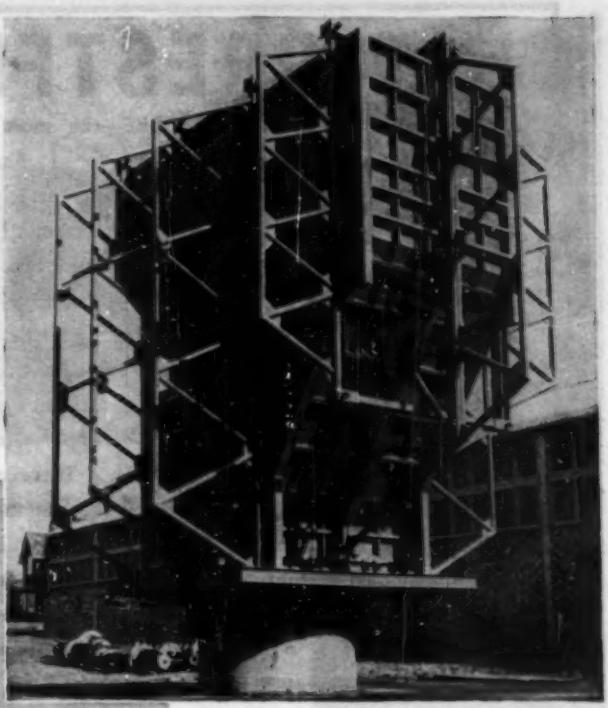
Sheets of moulded wood-fibre (*Fig.* 7) can also be used as liners. The illustration shows a sheet, 6 ft. by 8 ft., made up by stapling together pieces 12 in. square, each piece containing four indentations. The sheet can be used with either face towards the concrete, depending on whether an indented or projecting pattern is required.

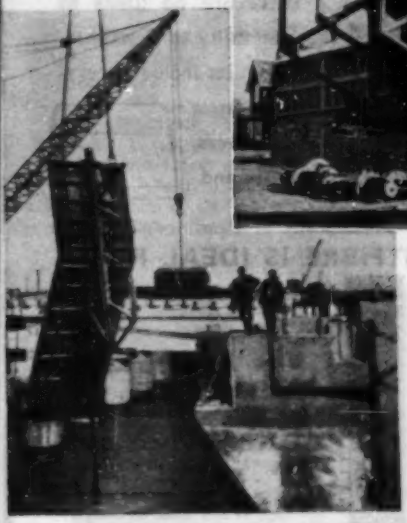
Rubber linings can be used to produce patterns comprising linear, round, chequer, waffle or square indentations, but many of these patterns were devised for purposes other than the decoration of concrete. Two dissimilar patterns produced from rubber linings are shown in *Figs.* 8a and 8b. The crêpe texture shown in *Fig.* 8b was applied to the precast wall slabs for a factory at Margaret, near Swindon (*Fig.* 9). (The chequer pattern in *Fig.* 8a is similar to that formed by steel chequer-plates with which the shutters are being lined to produce indented surfaces on the construction joints in the concrete of the coast-protection works near Rotterdam.) If rubber is used as a lining, a vegetable mould oil is required since a mineral oil is detrimental to the rubber. The liner is prepared by pouring cold rubber latex over a plaster pattern. The principal deterrent to using rubber liners extensively is that the repeated contact with moisture and oil combined with the effects of the heat generated when the concrete sets causes the rubber to warp and eventually perish.

Acknowledgements.

FIG. 3.—The block of flats was designed and constructed by Messrs. Wates Ltd., the consulting engineers being Messrs. W. V. Zinn & Associates.

Consultants: Sir William Halcrow & Partners
Contractors: The Demolition & Construction Co Ltd





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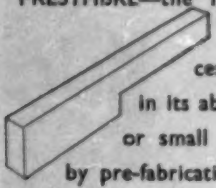

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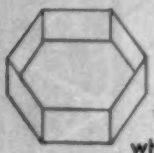

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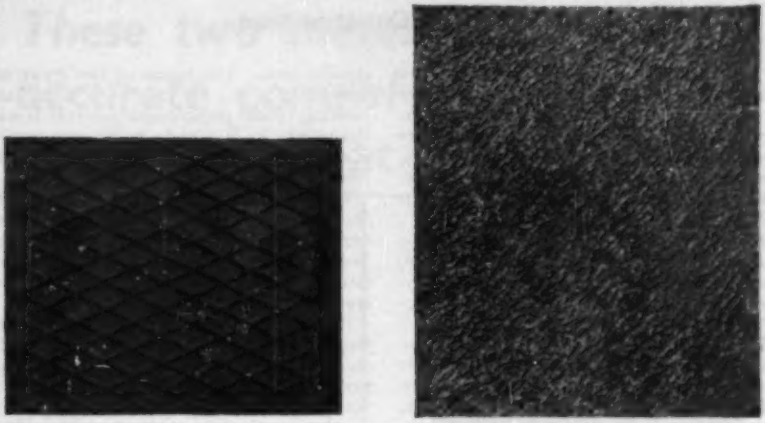


(a) (b)

Fig. 8.

FIG. 7.—Prestfibre Ltd.

FIG. 8.—Natural Rubber Development Board.

FIG. 9.—Architect: Mr. Bertram Carter, F.R.I.B.A. Contractors: Messrs. Holland & Hannen and Cubitts Ltd.

FIGS. 1, 4, 5 and 6.—These are illustrations of some of the display panels at the research laboratories of the Cement and Concrete Association at Wexham Springs. The panel in *Fig.* 4 was designed by, and the shuttering was prepared by Mr. W. Mitchell. The pattern in *Fig.* 5 was designed by Mr. J. D. Binns and the blocks were made by Modular Concrete Co., Ltd. The blocks in *Fig.* 6 were made by Girlings' Ferro-Concrete Co., Ltd.

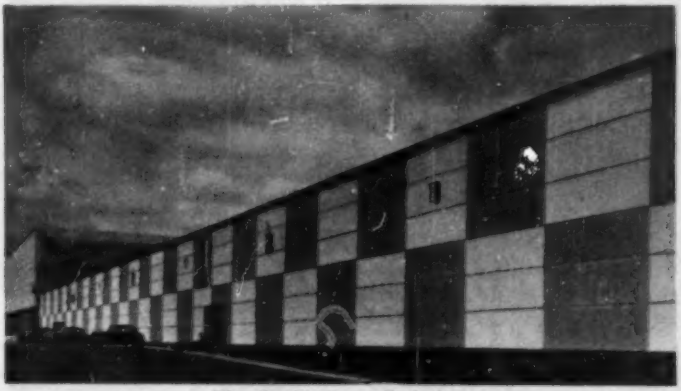


Fig. 9.—Factory, Swindon.

Speed of Construction.

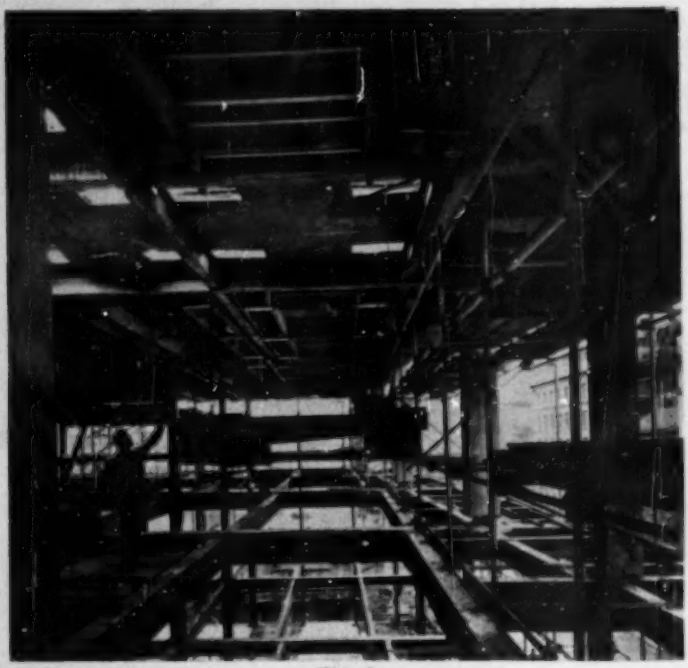
In the Editorial Notes in this journal for June last, reference was made to a number of unidentified buildings the rates of construction of which were notable for their speediness. Some of these structures, and the architects, engineers and contractors associated therewith, are identified in the following.

Eighteen-storey Hotel, London.—Carlton Tower Hotel, Cadogan Place, Chelsea. Architect: Mr. Michael Rosenauer. Structural designers and contractors: Sir Robert McAlpine & Sons Ltd.

The building is 208 ft. high and the main tower block is supported on cylinder piles, the shafts of the largest of which are 7 ft. in diameter with bases of 15 ft. diameter, and carry about 1000 tons. Stability of the reinforced concrete frame is provided by a concrete lift-shaft and cross-walls. The wind pressure on the tower block was assumed to be 17 lb. per square foot. The spans of the floors are generally 20 ft., but over the main banqueting rooms prestressed concrete beams spanning 53 ft. and each supporting 110 tons. The beams contain post-stressed ½-in. strands.

Departmental Store, Glasgow.—For Messrs. Arnott Simpson Ltd., Argyle Street, Glasgow. Architect: Mr. Gordon Jeeves. Consulting engineers: Messrs. George Davie, Crawford & Partners. Contractors: Messrs. Leslie & Co., Ltd.

The concrete roof of this four-storey building was constructed as soon as the steel frame had been erected. Construction of the top floor then proceeded. For the roof and upper floors, panels of shuttering, the largest of which was 25 ft. by 8 ft., were prefabricated and supported on the steelwork. After the slab had been constructed, the shutters were lowered, by winch, through the steel frame to the next



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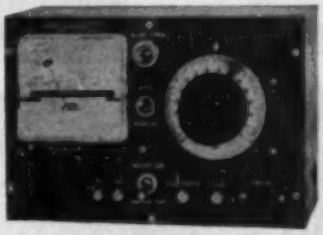

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floor (*Fig.* 1) without the need to dismantle the panels. To ensure the safety of the workmen, the shutters were so designed that at no stage was there the need for anyone to work on the bare steel frame. All operations were carried out on top of the shutters or on the concrete slab.

LAUNDRY.—Sunny Bank Laundry, Wadhurst, Sussex. Manufacturers and erectors of precast concrete frame: Messrs. E. W. Tyler & Co., Ltd.

This small building is 55 ft. long and 20 ft. wide.

FACTORY, LIVERPOOL.—For British Enka Ltd., at Aintree. Architects: Messrs. Harry Banister & Partners. Consulting engineer: Mr. D. S. Grave. Contractors: Messrs. Holland & Hannen and Cubitts (North West) Ltd.

The eight new buildings in this scheme are erected in the grounds of an existing factory where cellulose is used extensively. Highly explosive CS_2-gas, which is used in some parts of the factory, has seeped into the soil and, when driving the casings for the cast-insitu foundation piles, the impact of the hammer was sufficient to explode the gas and to cause flames to shoot many feet upwards. To prevent these explosions, CO_2-gas was forced into the bores to form an inert blanket, thus excluding oxygen and preventing it from combining with the CS_2-gas.

FIVE-STOREY BLOCK OF FLATS, FRANCE.—This building is at Asnières, and the construction comprises about 1200 precast members of the largest size practicable. The smallest weigh about 1¼ tons and the largest 7 tons. The precast floor slabs are 7½ in. thick and cover an area of 135 sq. ft. The wall panels are 10 ft. 9 in. wide and 8 ft. 9 in. high, and comprise 6½ in. of ordinary reinforced concrete with an external facing of white concrete and, on the inside, a ¾-in. insulating layer of polystyrene covered by a 1½-in. layer of concrete. Architect: M. Riot. Designers and contractors: Société Constructions Edmond Coignet. A description of this work is given in "Travaux," March 1960.

• • •

References to other publications are as follows.

"Structural Achievement in Concrete."—A brochure published in 1961 by the Reinforced Concrete Association.

"The Effect of Design on the Speed of Construction."—Yerbury Foundation Lecture given by Mr. A. Raymond Mais, O.B.E. (Managing Director, Messrs. Trollope & Colls Ltd.), at the Royal Institute of British Architects, November 1960.

Revised British Standard for Mild Steel (B.S. 15: 1961).

BRITISH Standards No. 15, which was first published in 1906 and is entitled "Specification for Mild Steel for General Structural Purposes", has been revised. Since the previous edition was published in 1948, there have been developments in steel-making, particularly in the application of oxygen, and provision is made for such developments. The steel now specified has a maximum carbon content of 0·25 per cent., and is suitable for welding. The process of manufacture and limits for contents of carbon, copper, sulphur, and phosphorus are specified. Details of the tests to be carried out on plates, rolled sections, round and square bars, rivet bars and rivets are given, and the strengths and other physical properties of steel for these various purposes are specified.

Copies of the Standard are obtainable from the British Standards Institution, 2 Park Street, London W.1 (Price 5s. each).

An Electrical Heater for Aggregates.

AN electrical apparatus for heating fine or coarse aggregate is now available in the form of rod which is pushed into a heap of the material. When the current is switched on, the heat dissipates throughout the heap and prevents freezing of the moisture in the heap or thaws frozen material. The apparatus is supplied by Eltron (London) Ltd.

FIFTY YEARS AGO.

From "Concrete and Constructional Engineering", December, 1911.

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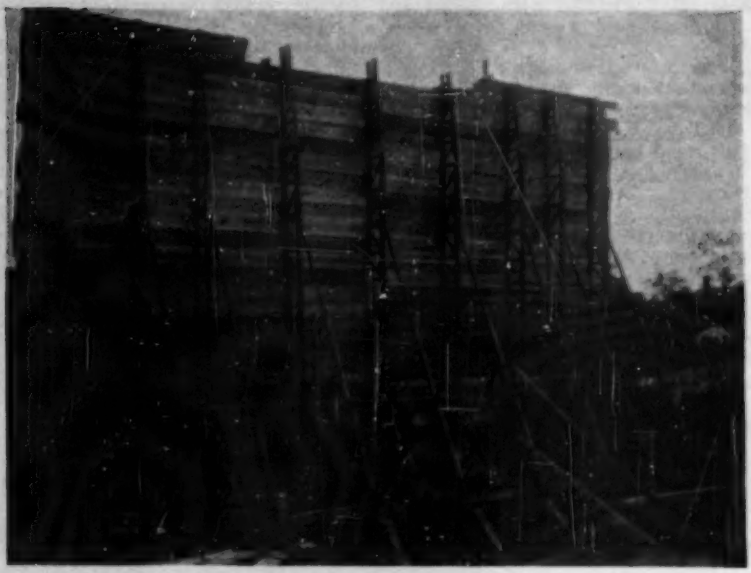

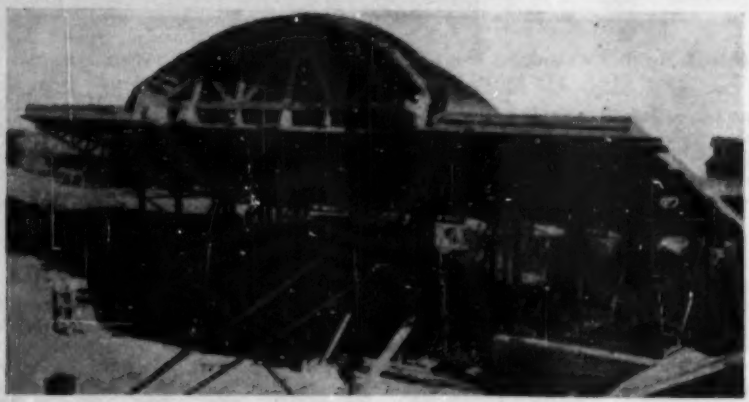

"The accompanying illustrations show a novel method of reinforced concrete construction, which consists of casting the walls on the ground and then raising them into position by means of jacks set on the foundation wall and on piles inside the building. These jacks consist of a supporting carriage, a pivoted walking beam, and a collapsible screw driven by a worm-gear. A platform is laid on the jacks and on

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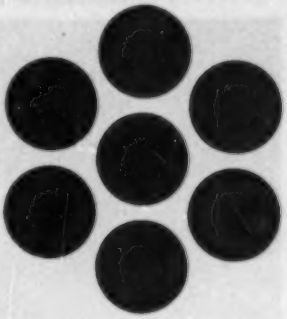

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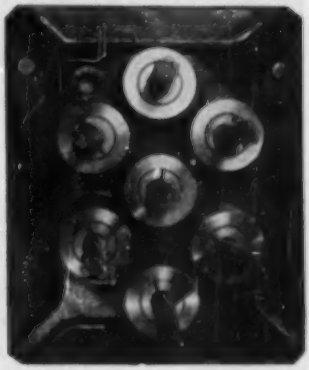

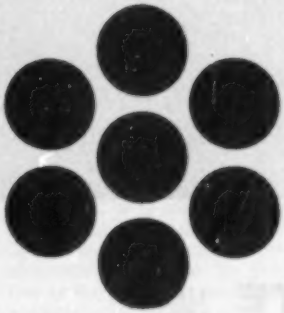

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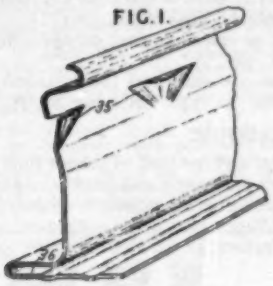
this platform are set all door frames, window frames and other openings. The reinforcement is easily placed horizontally and vertically in its exact position. The entire wall is poured at once, which can be done in a single day, even though the wall be 200 ft. long and three storeys high. After the wall is finished it is allowed to set for forty-eight hours, then a small engine or electric motor is connected with the driving shaft, and the wall rises from the inside slowly to its permanent vertical position."

Patent Applications for Reinforcement.

A REINFORCING member (*Fig.* 1) for concrete is rolled from sheet steel to the profile shown. Pockets 35 and the corrugations 36 assist keying to the concrete. —No. 830,885. Moderner Bau-Bedarf G.m.b.H. August 8, 1958.

FIG. 1.



A COLD-TWISTED reinforcing rod for concrete has a core 1 and ribs 2 extending around and along the length of the core, at least one rib having flanks or portions thereof which denote in relation to the longitudinal line of symmetry of the rib. Such a rib may have a wavy form, e.g. as *Fig.* 1b, or it may have a width which is alternately increased and decreased. Core 1 may be of circular cross-section; alternatively it may be polygonal with ribs at the polygon corners and also intermediately.—No. 861,132.

A CONCRETE reinforcing rod 1 has at least one continuous longitudinal rib 2 and additional short ribs 3, the rod being cold-twisted so as to give rib 2 a helical form. Ribs 3 extend obliquely with respect to the axis of the twisted rod and at a shallow angle to rib 2 (*Fig.* 2). Ribs 3 may all incline in the same angular direction relative to rib 2 or alternately in opposite directions.—No. 868,077.

The two foregoing applications were registered by Tor Isteg Steel Corporation in 1957.

FIG. 1b.

FIG. 2.

Reinforced Concrete Association.

THE subject of the meeting of the Reinforced Concrete Association to be held at the Royal Aeronautical Society in London on January 7, 1962, is " Tall Buildings in Concrete In-situ and Precast ".

The Millbank Tower, an office building of thirty-four storeys in Westminster (see this journal for January 1961), will be described by Mr. G. W. Kirkland, M.B.E., and Mr. D. M. Fountain, M.B.E.

The Hide Tower, which comprises twenty-three storeys and is the highest residential building in London (see this journal for April 1961), will be described by Mr. Charles Weiss and Mr. W. Pitman.

LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY

Short Course on Reinforced Concrete Bridge Design

A short course for civil and structural engineers will be held on Thursday and Friday, 18th and 19th January, 1962, and will deal mainly with the methods of design which have resulted from the research work carried out at the Cement and Concrete Association Laboratories during the last few years.

Fee: £1 2s. 0d.

Full details and application forms (returnable by 1st January, 1962) are available from the Head of the Department of Civil Engineering and Building.

DATA FOR PRICING REINFORCED CONCRETE.

MATERIALS (*Delivered London*).

AGGREGATES (per cu. yd.).

Washed sand: 26*s.* 9*d.* Graded gravel (¾ in.): 24*s.* 3*d.* Pit ballast: 25*s.* 6*d.*

CEMENT (per ton).

Ordinary Portland.—8 tons and upwards: 115*s.* 3*d.*

Rapid-hardening Portland: As ordinary Portland plus 10*s.* 6*d.* "Aquacrete" and "417": As ordinary Portland plus 32*s.* 6*d.* "Colorcrete" (buff, red, and khaki): As ordinary Portland plus 60*s.* "Snowcrete" (white): 280*s.* 9*d.*

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High-alumina cement.—6 tons: 314*s.* 6*d.*

"Super Snowcem" waterproof cement paint: 100*s.* per cwt.

REINFORCEMENT (per ton ex stock including delivery in quantities from 10 to 500 tons).

Plain mild steel rods per B.S. No. 785.—1 in. and over: £50 15*s.*; ⅞ in. and ¾ in.: £51 10*s.*; ⅝ in.: £52 5*s.*; ½ in.: £53 18*s.*; ⅜ in.: £55 8*s.* 6*d.*; ¼ in.: £59 9*s.* 6*d.*

Hot-rolled deformed bars: As plain bars plus £1.

High-tensile (minimum yield point 44,000 lb. per sq. in.): As mild steel plus 19*s.*

(For basic prices and allowances for quantities exceeding 500 tons and extras for quantities less than 10 tons, lengths greater than 40 ft. or less than 5 ft., bundling, labelling, and delivery in other areas, see "Concrete Year Book, 1961".)

Fabric per B.S. 1221A (per sq. yd.).—No. 109: 3*s.* ¾*d.*; No. 121: 5*s.* 7½*d.*; No. 124: 3*s.* 4½*d.*; No. 125: 2*s.* 10½*d.*; No. 126: 2*s.* 7*d.*

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Suspended slabs (per sq. yd.).—6 in., 19*s.* 6*d.*; 7 in., 22*s.* 9*d.*; 9 in., 29*s.* 3*d.*

Beams (per cu. ft.).—4*s.* 4*d.* Columns (per cu. ft.).—4*s.* 11*d.*

Walls (per sq. yd.).—6 in., 21*s.* 5*d.*; 9 in., 32*s.* 1*d.*; 12 in. and over (per cu. ft.), 3*s.* 9*d.*

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⅝ in.	79*s.* 8*d.*	86*s.* 2*d.*	83*s.* 7*d.*	—
½ in.	88*s.* 0*d.*	95*s.* 10*d.*	93*s.* 3*d.*	—
⅜ in.	89*s.* 8*d.*	97*s.* 6*d.*	94*s.* 11*d.*	109*s.* 4*d.*
⅛ in.	91*s.* 11*d.*	99*s.* 9*d.*	97*s.* 2*d.*	111*s.* 7*d.*
¼ in.	93*s.* 0*d.*	100*s.* 10*d.*	98*s.* 3*d.*	112*s.* 8*d.*

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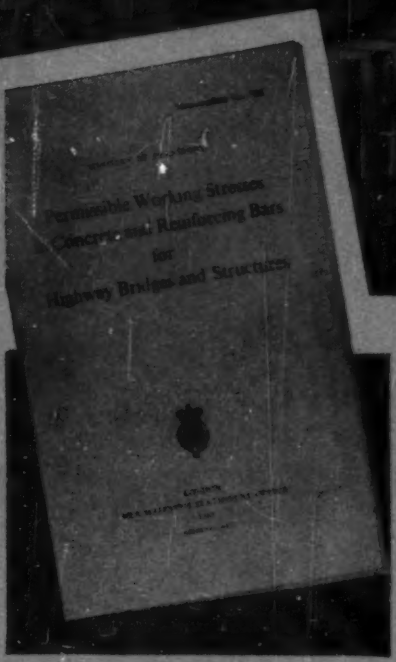

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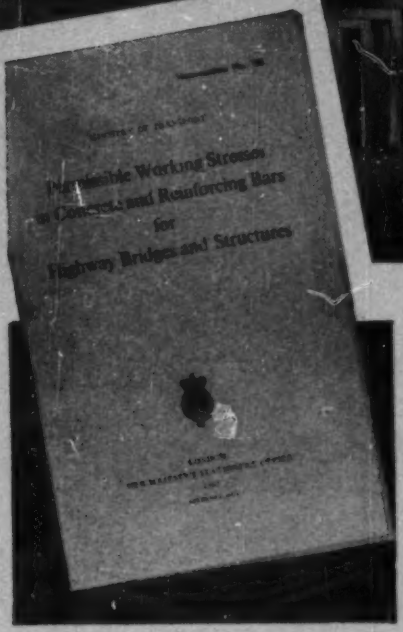

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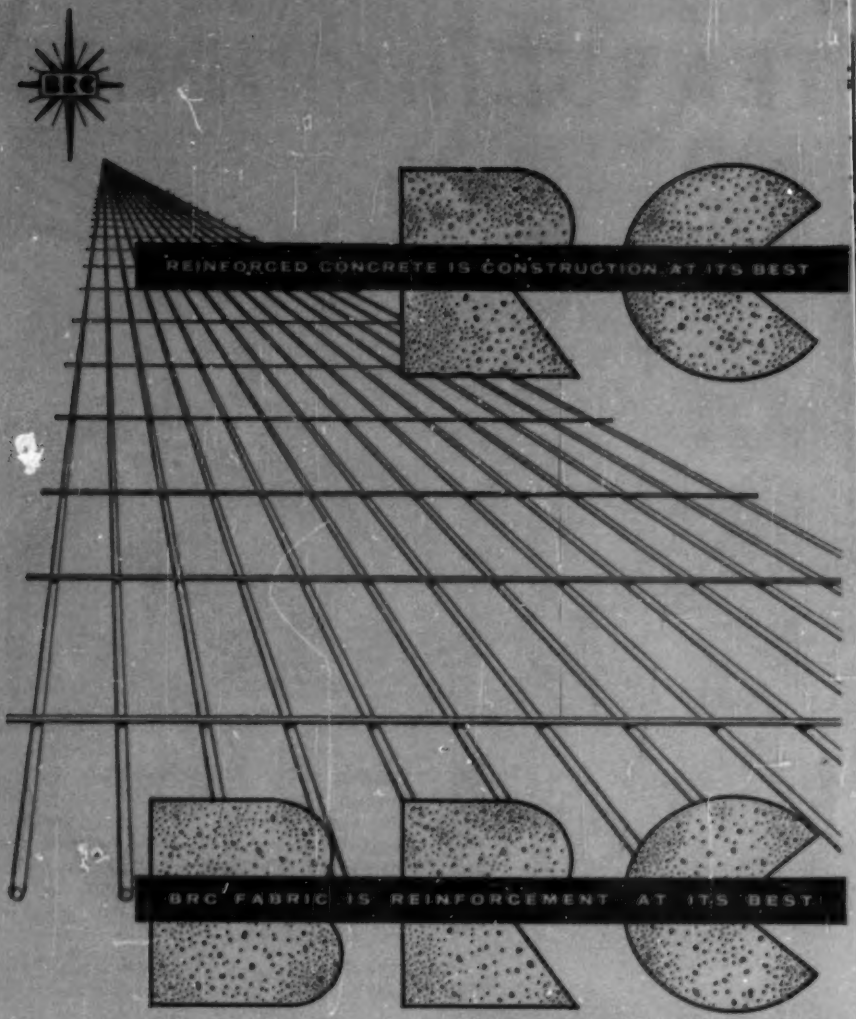

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